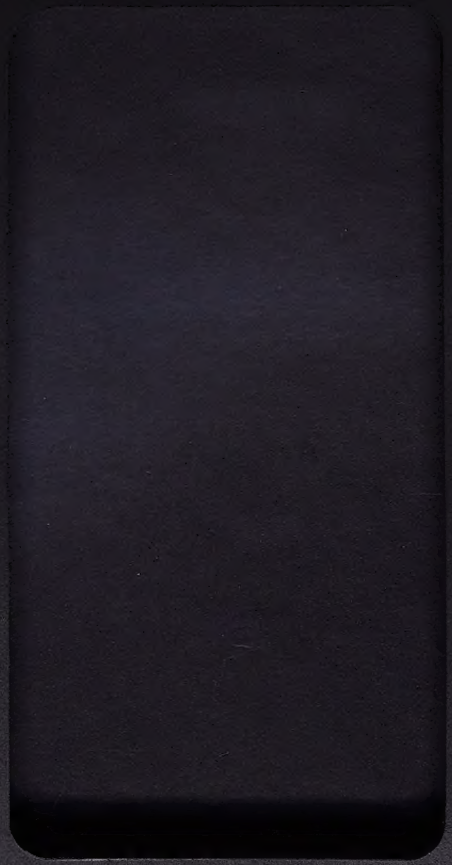
INSTRUCTION MANUAL

SD101A-MK III
DYNAMIC ANALYZER

SPECTRAL DYNAMICS CORPORATION OF SAN DIEGO



SERIAL NUMBER 1230

INSTRUCTION MANUAL

SD101A-MK III
DYNAMIC ANALYZER

(PART ONE)

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1 June 1965

(Revised April 1967)

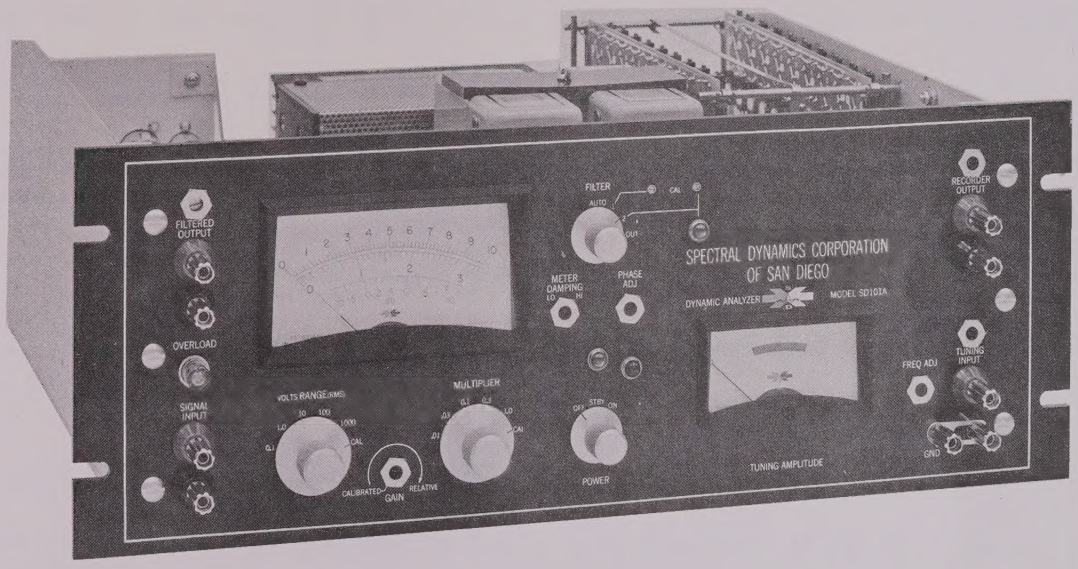
CAUTION

The oven control circuits for temperature stability of the SDC Model SD100-AR series crystal filters are dependent on a reasonably undistorted sinusoidal waveform applied to the instrument from the main a-c power source. Direct connection of the instrument to the a-c power source will invariably meet this requirement.

However, the use of certain harmonic-type magnetic voltage regulators in series between the power source and the instrument may produce, in addition to voltage regulation, a frequency waveform far removed from that of a sinewave.

Excessive distortion of the sinusoidal waveform will cause the oven control circuits to improperly cycle and, in fact, remain in the "ON" state continuously, thus resulting in severe damage to the crystal filters.

If the use of a voltage regulator is deemed necessary, it is highly recommended that thorough consideration be given to the quality of its output waveform. As a rule, distortion should not exceed 10%. The above also applies to most inverter-type power supplies unless specifically designed for sinusoidal output.



Model SD101A Dynamic Analyzer

PACKING

The Model SD101A Dynamic Analyzer is shipped fully assembled in a polystyrene carton which protects the instrument against all normal shipping hazards. To determine possible damage during shipment of the instrument, the procedures given below should be followed:

a. Place the carton upright on the floor and inspect the exterior, making note of any visible damage.

b. Remove and retain all forms and invoices attached to the carton by the carrier.

c. Unseal the top portion of the carton and remove.

d. Lift the instrument out of the carton and place it on a work bench or other flat surface.

e. Inspect the exterior of the Dynamic Analyzer carefully, noting all visible damage.

f. The Dynamic Analyzer may now be checked for functional operation by following the procedure outlined in Section II.

CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be tested as soon as it is received. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report forwarded to Spectral Dynamics Corporation of San Diego. The buyer will be advised of the disposition to be made of the equipment and arrangements shall be made for repair or replacement. Include Name, Model Number and Serial Number when referring to this instrument for any reason.

WARRANTY

Spectral Dynamics Corporation of San Diego warrants each instrument manufactured by them to be free from defects in material and workmanship for one year after delivery to the original purchaser. Our liability under this warranty is limited to servicing and adjusting the instrument returned to the factory with transportation charges prepaid by the purchaser. This warranty specifically excludes any liability in regard to electron tubes, batteries, fuses and lamps. If the fault or a portion thereof is determined by us to have been caused by misuse or abnormal conditions of operation, an estimate will be submitted to the purchaser prior to starting the work on the repairs.

If any fault develops, the following steps should be taken:

1. Notify us or our representative in your area, giving full details of the problem, including name, model and serial number of the equipment. Upon receipt of this information, we will submit service data or shipping instructions.

2. On receipt of shipping instructions, forward the instrument prepaid, to the factory or authorized repair station indicated on the instructions.

SHIPPING

All shipments to the factory should be made via Air Freight. The instrument should be replaced in its original shipping carton or in a strong exterior container surrounded by two or three inches of excelsior or similar shock-absorbing material.

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SECTION I

GENERAL INFORMATION

1-1. INTRODUCTION.

The Dynamic Analyzer is a newly developed multipurpose instrument offering exceptional application versatility in the fields of vibration, acoustical and electrical analysis and measurement. Essentially, the analyzer is a frequency-tuned bandpass filter which is frequency-tuned inherently, without depending upon an internal servo, frequency to DC conversion, or phase-lock principles for its unique operation. The center frequency of a selected passband is continuously and precisely tuned to track a frequency from an external source. Figure 1 illustrates the concept of operation.

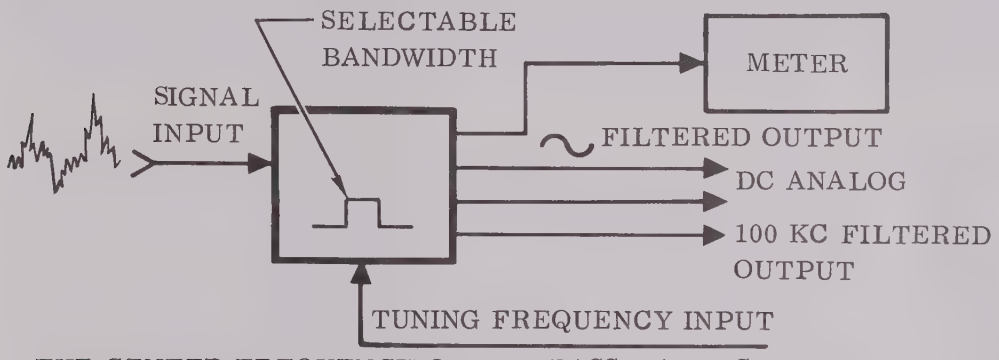


Figure 1. Concept of Operation

The frequency to which the SD101A is to be tuned is applied to the tuning frequency input. The center frequency of the selected passband is then virtually instantaneously tuned to this external frequency and as the tuning frequency input varies in frequency the center frequency of the passband continuously tracks the tuning signal frequency. The signal to be filtered is applied to the signal input of the analyzer and the SD101A provides four outputs representing data signals falling within the passband: (1) a meter; (2) a DC analog and (3) a filtered signal output and (4) a 100 KC filtered output.

1-2. GENERAL DESCRIPTION.

The instrument is packaged on a 7" × 19" standard panel and a chassis that extends 14" behind the front panel. The chassis has bottom and top dust covers which are

perforated for ventilation and are easily removed during maintenance. The top cover should be removed when the equipment is mounted in a closed console. The front panel (figure 2) contains the necessary operating controls, meters, calibration controls and input-output jacks to perform routine calibrating and operating functions. The following is a list of the front panel items and a brief description of their functions.

Power Switch (12)

This selector applies power to the instrument. The STANDBY position applies power to the power supply, the tube filaments and to the ovens for the oscillator crystal and crystal filters. The amber light above the POWER switch denotes the standby position. The ON position of the POWER switch applies B+ to the tubes, and is denoted by a green light.

Signal Input (16)

The signal that is to be analyzed or filtered is applied to these terminals. This input is paralleled to a connector on the rear of the equipment for use when rear wiring is desired.

Overload Indicator (17)

The light located directly above the Signal Input terminals informs the operator when a circuit overload condition exists. The light is normally adjusted to operate with a crest factor (peak/RMS) of approximately 4 to 1.

Tuning Input (9)

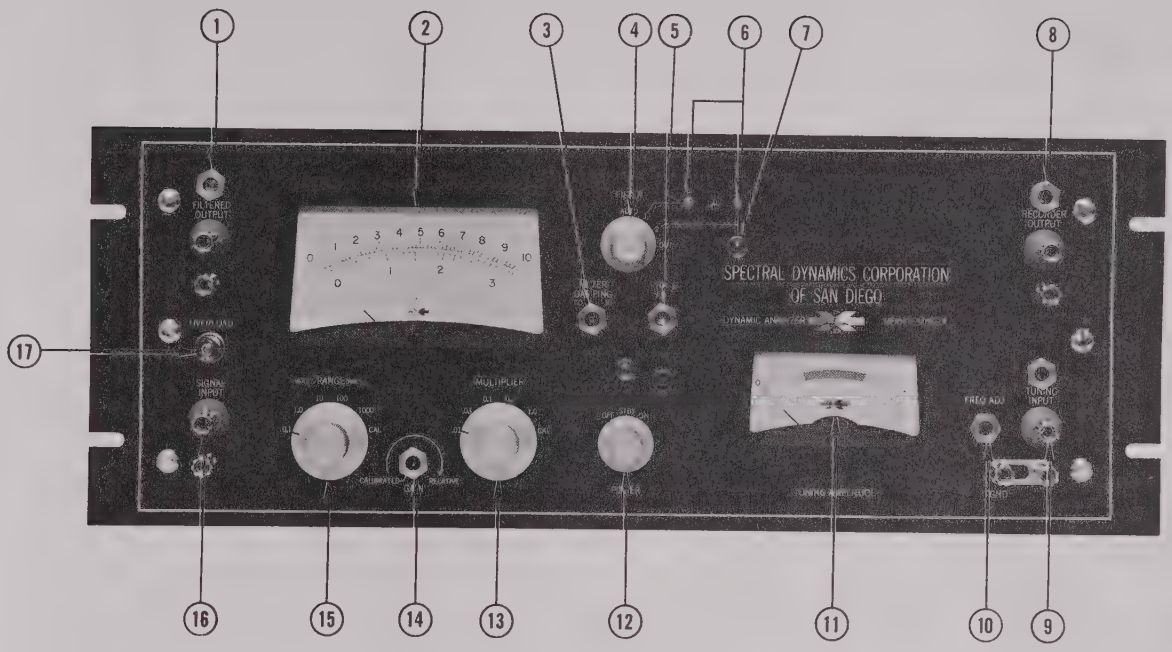
The external tuning signal used to tune the analyzer is applied to these terminals. This input is also available on the rear of the chassis. The front panel terminal labeled GND is connected to the chassis and the black terminal is connected to circuit ground. The instrument may be operated in the floating or non-floating mode depending on the connection of the terminal shorting link.

Tuning Amplitude Meter (15)

The small meter displays the amplitude of the tuning signal input. A red band on the face of the meter provides a range of the proper operating level. This level can be adjusted by use of the screwdriver adjustment located directly above the tuning input terminals.

Frequency Adjust

This screwdriver adjustment (located between the tuning amplitude meter and the tuning input terminals) is used to adjust the reference oscillator frequency to the center frequency of the crystal filter. It is used during routine calibration procedure.



1 FILTERED SIGNAL OUTPUT
2 SIGNAL METER
3 METER DAMPING
4 FILTER SELECTOR
5 PHASE ADJUST
6 FILTER NORMALIZING POTENTIOMETERS
7 CROSSOVER INDICATOR
8 RECORDER OUTPUT
9 TUNING SIGNAL INPUT
10 FREQUENCY ADJUST
11 TUNING AMPLITUDE METER
12 POWER SWITCH
13 MULTIPLIER SELECTOR
14 GAIN ADJUST
15 RANGE SELECTOR
16 SIGNAL INPUT
17 OVERLOAD INDICATOR

Figure 2. Front Panel

Filter Selector

Used to manually select the desired plug-in crystal filter, or to provide for automatic bandwidth switching (AUTO position. See SD21 manual). The OUT position connects the input signal directly to the Filtered Signal Output terminals, completely bypassing the analyzer.

Filter CAL adjustments

An output adjustment is provided on the front panel for each filter. They are required to normalize the insertion loss of the plug-in crystal filters and thus establish the correct overall gain of the analyzer.

Crossover Indicator

The amber lamp located directly below the number two filter CAL adjustment is the filter crossover indicator. It is illuminated in either the manual or the automatic operating mode when filter two is selected.

Meter Damping

The screwdriver-adjustable switch located below the filter selector allows the operator to select HIGH or LOW damping circuits for the meter.

Phase Adjustment

The screwdriver phase control located adjacent to the Meter Damping switch is used to adjust the input to output phase angle or the relative phase between units in a multichannel system. This control is also used in cases where the SD101A is used in sine-reject applications. It provides a phase adjustment of approximately 115 degrees. If the desired phase adjustment cannot be obtained by this control, the Phase Invert switch located on top of the chassis can be switched to provide an additional 180-degree phase shift.

Range Selector

The RANGE switch is calibrated in volts (RMS) and operates the attenuator on the input of the instrument. The amplitude of the incoming signal should not exceed the selected range. In the CAL position, a calibration signal is applied internally to the instrument.

Multiplier Selector

The MULTIPLIER switch operates an attenuator just preceding the meter amplifier. The combination of the readings on the switch and the RANGE selector provides the operator with the selected meter range. When performing the internal CAL procedure the MULTIPLIER should be placed in the CAL position.

NOTE

CAL and 1.0 on the multiplier are common internally.

Signal Meter (12)

The signal meter contains three scales that are selected by use of the RANGE and MULTIPLIER selectors discussed above. One scale is calibrated in DB while the other two are calibrated in RMS voltage.

Gain Adjust (14)

This screwdriver adjustment is used to adjust the gain of the system during routine calibration procedure or when making relative amplitude measurements. When making relative measurements the gain control provides an 18 DB range of adjustment.

Filtered Signal Output (13)

The filtered signal output is the signal amplitudes and frequency or frequencies contained in the passband of the instrument. The output level can be adjusted as desired by the adjacent screwdriver control. This output is also available from a rear connector.

Recorder Output (8)

A DC voltage, proportional to the average amplitude of the signals contained in the passband is available at these terminals. The DC level is adjustable by use of the screwdriver adjustment directly above the terminals. The recorder output is available from a rear connector.

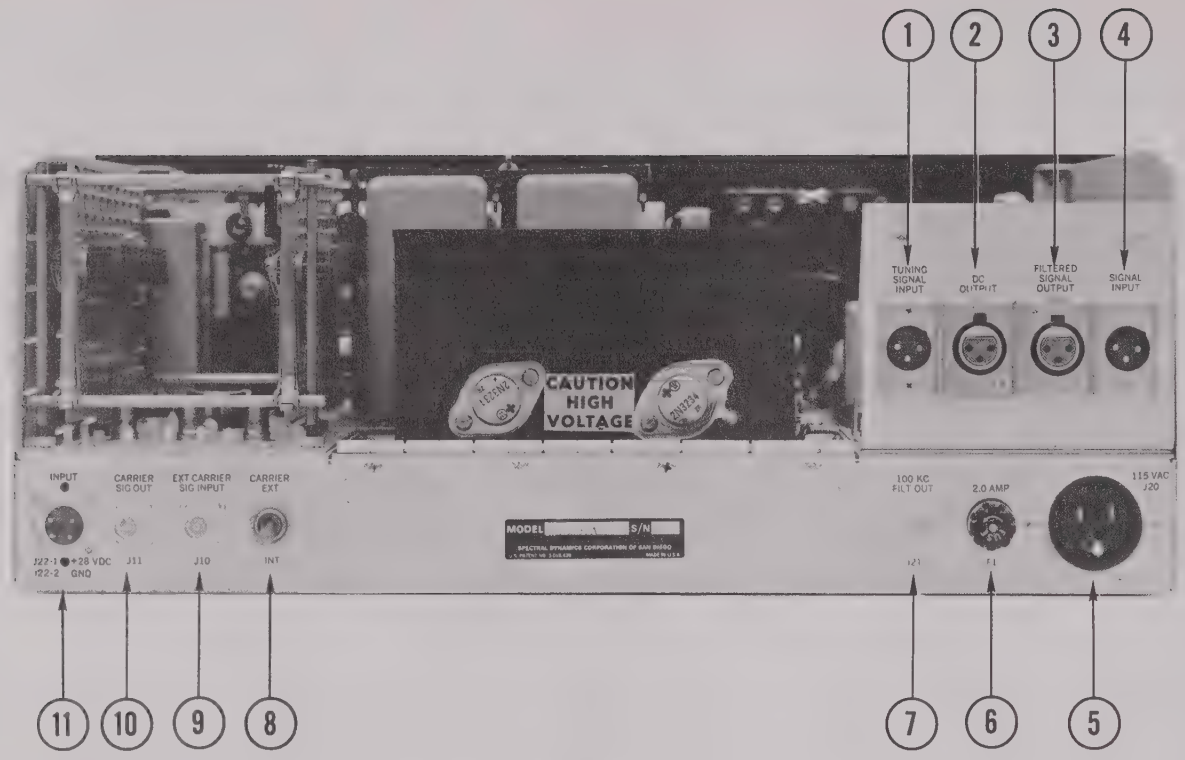
In addition to the connectors that are paralleled to the input and output terminals on the front panel, the following items are also located on the rear of the chassis: (See figure 3.)

Carrier Selector

The toggle switch is used to select the internal carrier signal, produced by the reference oscillator and tuning signal, or an external source. In the external position, this switch also disconnects B+ from the carrier converter section.

External Carrier Input (9)

This BNC-type connector is provided to facilitate the use of an external carrier signal for tuning the SD101A. For example, two SD101A Analyzers can be tuned by a common source simply by connecting the CARRIER OUTPUT of the first SD101A to the EXTERNAL CARRIER INPUT of the second SD101A and switching the CARRIER SELECTOR of the second SD101A to the EXT position. Then with a tuning signal applied to the TUNING INPUT of the first SD101A, both SD101A Analyzers become tuned by a common carrier signal.



1 TUNING SIGNAL INPUT (J8)
2 DC OUTPUT (J6)
3 FILTERED SIGNAL OUTPUT (J5)
4 SIGNAL INPUT (J7)
5 POWER INPUT (J20)
6 FUSE (F1)
7 100 kHz FILTERED OUTPUT (J21)
8 CARRIER SELECTOR (S4)
9 EXTERNAL CARRIER SIGNAL INPUT (J10)
10 CARRIER SIGNAL OUTPUT (J11)
11 28 VDC INPUT (J22)

Figure 3. Rear Chassis View

28VDC Input (J22)

Available as optional equipment are proportional-control type filters designated as Model SD100APC, and proportional-control 100 kc crystal ovens. If these proportional-control type devices are used, suitable dc power must be supplied through connector J22. Each filter oven requires approximately 750 ma at room temperature turn-on, decreasing as the filters warm up. Starting current for the crystal ovens is approximately 150 ma. Power supply voltage should be 28 volts dc, plus or minus 1 volt, with plus or minus 0.5% regulation or better. Note: Observe polarity; pin 1 is positive and pin 2 is negative. Pin 2 is internally connected to circuit ground. If the SD101A is to be operated in the "floating" mode, (removal of the front panel shorting link), the dc power supply connected to J22 must also be "floated".

1-2. GENERAL DESCRIPTION (Cont'd)

Input/Output Connectors

The four input/output connectors located on the rear of the chassis are in parallel with the front panel input/output terminals.

Fuse

115 volts ac operation - 2 A, slo-blo type.
230 volts ac operation - 1 A, slo-blo type.

Power Input

The power input receptacle accepts a standard 3 prong type power plug.

Carrier Output

BNC type connector for multi-channel systems. An example of its use is given in the explanation for External Carrier Input.

1-3. SPECIFICATIONS

Frequency Range: 2 - 25,000 Hz

Useful Frequency Range: 1 - 30,000 Hz

Frequency Response:

Recorder

±0.25 dB over operating frequency range.

Meter

±2% of full scale

Filtered Signal Output

±0.25 dB from ½ BW to 10 kHz; response falls off gradually above 10 kHz down approximately 1 dB at 25 kHz.

Notes: (1) The operating frequency range is defined as the frequency equal to ½ the bandwidth of the filter in use to 25 kHz.

A filter having a bandwidth of 5 Hz, the operating frequency range would be ½ BW = 2.5 Hz to 25 kHz. If the BW is 20 Hz, operating frequency range is 10 Hz to 25 kHz.

(2) The SD101A may be used below the frequency equal to ½ BW if some degradation in performance is acceptable.

1-3. SPECIFICATIONS (Cont'd)

Dynamic Range:	Meter Circuit 60 dB Filtered Signal Output 60 dB Linear d-c Output 40 dB
Residual Noise:	60 dB below full output; with input terminals shorted.
Linearity:	Meter Circuit ±3% of F.S. DC Output ±0.25 dB FSO ±0.25 dB, 40 dB continuous range
Sensitivity: (Range)	1 mV - 1000 V
Input Impedance:	1 MΩ
Tuning Signal:	0.2 V rms minimum input required (sinusoidal with less than 5% distortion). Allowable amplitude variation approximately 7 dB.
Selectivity:	Accommodiations for two plug-in crystal filters. Standard bandwidths available for 2, 5, 10, 20, 50 and 100 Hz. The shape factor (60 dB/3 dB bandwidth) of each filter is nominally 4 to 1.
Calibration:	Internal reference.
Tracking Rate:	In excess of 20,000 Hz/sec.
Outputs:	(1) Recorder 0-1 Vdc into 100 kΩ . (2) Filtered signal adjustable; 10 V rms maximum into 10 kΩ .
Power:	115/230 Vac, 50/60/400 Hz, 120 W.
Inputs/Outputs:	Input/output terminals on the front panel are in parallel with input/output connectors on rear of chassis.
Size:	7" high, 19" wide, 14" behind panel (17,8 cm x 48,3 cm x 35,6 cm)
Shipping Weight:	34 LBS. (15,4 kg)

SECTION II

OPERATING INSTRUCTIONS

2-1. PRELIMINARY OPERATION CHECKS.

Meter Mechanical Zero

Check the meter mechanical zero. If the pointer does not rest directly over the zero with the power off, proceed as follows: A stable adjustment can only be made when the direction of pointer travel is opposite to the direction of rotation of the adjusting screw. The adjusting screw may be turned in either direction; however, the most effective method is to turn the screw clockwise until the pointer swings up-scale and then starts to swing down-scale toward zero. Continue turning the screw clockwise until the pointer (now moving to the left) is directly over the zero mark. If the screw is turned too far, continue turning clockwise until the pointer is again traveling down-scale toward zero. Tap the meter lightly to avoid any friction in the movement from giving a false indication of zero.

Carrier Switch

Check to see that the carrier INT/EXT toggle switch located on the rear of the unit is in the INT position.

Installation of Filters

Loosen the Camloc fasteners holding the top cover in place by turning the fasteners one-half turn counterclockwise. Rotate cover back (cover is rear-hinged), exposing the interior of the equipment. Plug in the crystal filters in the octal sockets marked A1 and A2 located on top of the chassis. A1 and A2 correspond to the front panel filter selector, Positions 1 and 2, respectively. Install narrowest filter in socket A1, wider filter in socket A2.

Filter CAL Potentiometers

The filter CAL potentiometers are multi-turn trimpots located on the front panel near the filter selector switch. The left-hand potentiometer adjusts the output of filter A1 and the right-hand potentiometer adjusts A2. The insertion loss normally varies between different filters; therefore, the SD101A must be recalibrated each time a different filter is installed.

2-2. OPERATION.

Filter Center Frequency Alignment and Sensitivity Calibration.

In the self calibrating mode, the unit's sensitivity is compared against the voltage output of an internal zener diode reference operating at the line frequency. The filter center frequency alignment relative to the tuning frequency, as well as the sensitivity calibration, is performed as follows:

a. Turn on power and allow unit to warm up approximately 45 minutes.

b. Turn RANGE and MULTIPLIER selectors to CAL position. This operation connects the internal reference to the input of the analyzer, and provides an internal tuning signal to the unit.

c. Turn the front panel GAIN control fully counterclockwise to the CALIBRATED position.

d. Turn FILTER switch to Filter 1.

e. Adjust the FREQUENCY control for a peak indication on the signal meter.

f. Adjust the Filter 1 CAL potentiometer for a meter reading of 7.

g. Select the broader filter (Filter 2) and without re-adjusting the FREQ control, turn the Filter 2 CAL potentiometer to obtain a meter reading of approximately 7 on the meter.

h. Turn RANGE and MULTIPLIER switches to appropriate positions (see para 2-3).

i. Apply the tuning frequency and data signal to their proper front or rear connectors. Adjust the tuning signal level control for centerline on the tuning meter.

2-3. SETTING THE RANGE AND MULTIPLIER SWITCHES.

Start measurements with the MULTIPLIER switch in the 1.0 position. Rotate the RANGE switch to obtain an up-scale reading. The purpose of this is to utilize the full dynamic range of the instrument. The filtered signal output is only affected by the RANGE control; therefore, the signal-to-noise ratios are primarily dependent on the RANGE setting.

CAUTION

This input level should not exceed the range control volts RMS. Higher values can overload the input amplifier. The Overload Indicator will indicate an overload condition.

The unit will withstand crest factors (peak/RMS) of approximately 4 to 1 when operating with the maximum RMS input. This ratio goes up proportionally as the input level is less than the range (RMS).

EXAMPLE: Range switch set at 1V RMS - input level 0.5V RMS. The input amplifier will now handle crest factors of 8 to 1. This becomes a factor when dealing with random or sine random-type of input signals. However, clipping the large transient peaks of a random signal will not appreciably affect the accuracy of measurement.

2-4. MAKING RELATIVE MEASUREMENTS.

When observing relative levels on the meter, the front panel GAIN control can be used to adjust the reading over an 18 DB range. Adjust for a full-scale reading with the MULTIPLIER on the 1.0 position. Re-establishing the instrument calibration on an absolute basis can be accomplished by rotating the gain control fully counterclockwise to the CALIBRATED position.

2-5. USE OF INTERNAL CAL SIGNAL.

The internal calibration signal applied to the input amplifier of the SD101A is used to perform filter alignment and sensitivity standardization of the SD101A.

In addition, the calibration signal provides a means for making single-point calibration of auxiliary readout equipment such as X-Y recorders, vibration meters, etc.

With the RANGE and MULTIPLIER in the CAL position a fixed-level 60-cycle tuning signal is applied to the Analyzer Tuning input, disconnecting the external tuning signal. A preset square wave with an equivalent fundamental sinusoidal amplitude of 70 MV RMS is connected to the input amplifier directly, bypassing the input range attenuator.

With the SD101A properly peaked and adjusted (Paragraph 2-2), the amplitude of a selected component of the input signal can be determined from the meter by multiplying the RANGE setting X MULTIPLIER setting = volts full scale.

When the SD101A is in CAL, output signals are obtained representing the output levels which would be produced by a 70 MV RMS signal applied to the input amplifier. Since an input signal must pass through the input RANGE switch the CAL signal represents a .7X range position during operation.

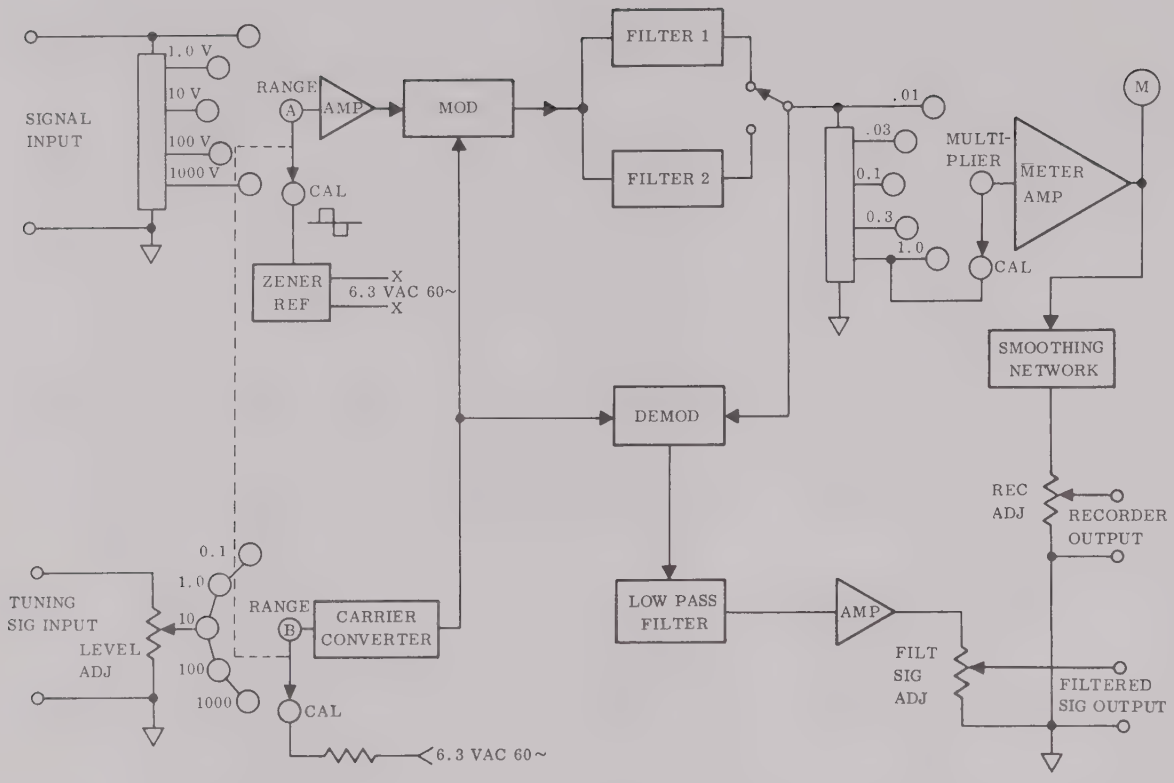


Figure 4. Block Diagram Showing CAL Circuits

NOTE

The Range Switch affects all outputs (Meter, Recorder, Filtered Signal). The Multiplier only affects the Meter and Recorder Circuits.

The MULTIPLIER changes the meter and recorder sensitivity 10 DB/step. An equivalent CAL output from the Recorder Circuit will increase 10 DB/step on the MULTIPLIER when in the operate mode. Therefore, the following formula is used for determining measured output levels when using the CAL signal before or after a data run to establish a single point calibration.

CAL Output Level = (Recorder Output)	.7 X Operating RANGE setting X Operating MULTIPLIER Setting. (RMS Volts)
CAL Output Level = (Filtered Signal Output)	.7 X Operating RANGE Setting (RMS Volts)

The RECORDER and FILTERED signal level adjustments can be used to adjust the output levels for scaling purposes.

These calibration signal outputs can be converted to g levels, velocity levels, etc., by dividing the above equations by the pickup sensitivity in V/g, V/IN./SEC, etc.

SECTION III

THEORY OF OPERATION

3-1. INTRODUCTION.

The SD101A can be considered to be divided into two relatively independent circuit sections:

1. Filtering and measurement section

2. Carrier Converter section

The two operate together to form the frequency-tuned bandpass filter concept. The basic theory of operation can be best explained by referring to the figure below.

The Carrier Converter functions to produce an output frequency that is the sum of the tuning frequency input and the 100 KC reference oscillator frequency. As an example,

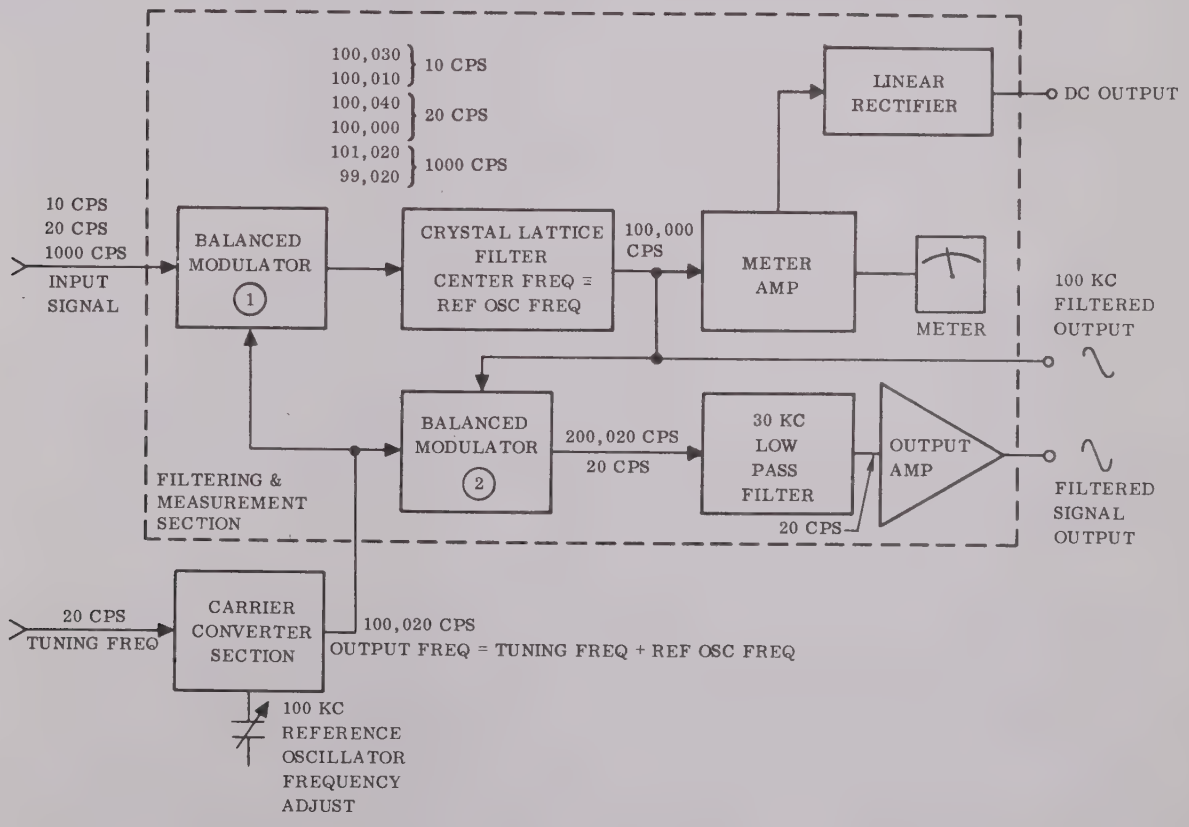


Figure 5. Simplified Block Diagram

with a 20 CPS tuning signal input the Carrier Converter produces an output of 100,020 CPS. Further, if the tuning frequency were to vary from 2 CPS to 25,000 CPS, the output from the Carrier Converter would be a frequency varying from 100,002 CPS to 125,000 CPS synchronously with the input tuning signal.

The frequency adjustment on the Reference Oscillator varies the reference frequency slightly so that the center frequency of the filter and reference oscillator frequency can be adjusted to the same frequency. The output of the Carrier Converter is then used to drive two (2) balanced modulators in the filtering and measurement section.

To show that the SD101A is adjusted to pass only frequencies lying within the passband of the filter, the following example is used:

Assume a complex signal applied to the input of the SD101A, consisting of three frequencies with different amplitudes - 1,000 CPS, 10 CPS, 20 CPS. Assume the Analyzer has a 10 CPS bandwidth filter.

Next, assume a tuning frequency of 20 CPS is applied to the tuning input terminals. The output of the Carrier Converter will be 100,020 CPS. The 100,020 CPS signal is applied to the balanced modulators 1 and 2. The output of balanced modulator 1 will essentially be the sum and difference of the signal frequencies and the Carrier Converter frequency. Since the Carrier Converter level is constant for all practical purposes (it can be considered constant since it is only supplying the switching voltage to the modulator), the amplitudes of the side band frequencies produced will be proportional to the amplitudes of the signal components at the Analyzer input. Therefore, at the output of modulator 1, we will have:

(100,020 + 20) = 100,040 CPS; (100,020 - 20) = 100,000 CPS; (100,020 + 10) = 100,030 CPS; (100,020 - 10) = 100,010 CPS; (100,020 + 1000) = 101,020 CPS; (100,020 - 1000) = 99,020 CPS

As can be seen from the side band components produced above, only the 20 CPS component amplitude will be passed through the crystal band pass filter, with all other components falling outside the pass band.

The output of the crystal filter is then passed to a meter circuit, indicating the amplitude of the signal passed by the filter and also to a rectifier circuit providing a DC output. Additionally, the output of the filter is fed to Modulator 2 where it is modulated with the Carrier Converter output. The output of Modulator 2 will be the sum and difference frequency of the Carrier Converter output frequency and the filter output frequency. Carrying the example through; the output of Modulator 2 will be (100,020 + 100,000) = 200,020 and (100,020 CPS - 100,000) = 20 CPS. The output of Modulator 2 is passed through a 30 KC low pass filter to reject the high frequency components, leaving only the 20 CPS component at the low pass filter output.

Next, injecting a tuning frequency of 1000 CPS would provide an output from the Carrier Converter of 101,000 CPS. This applied to Modulator 1 results in outputs of:

10 CPS input signal	20 CPS input signal	1000 CPS input signal
(101,010, 100,990);	(101,020, 100,980);	(102,000 and 100,000)

The 100,000 CPS signal will pass through the filter, and (1) its amplitude indicated by the meter circuit, (2) rectified to provide a DC analog output, and (3) fed to Modulator 2 where it is modulated with the 101,000 CPS signal, producing 201,000 CPS and 1000 CPS at Modulator 2 output. The 201,000 CPS component is rejected in the low pass filter, leaving only the 1000 CPS signal at the output.

Thus, from the above examples, it can be seen that the center frequency of the unit is tuned by the frequency of an external source.

Carrier Converter

The Carrier Converter produces an output frequency that is the sum of the tuning frequency and the reference oscillator frequency for tuning frequencies ranging from 2 CPS to 25 KCPS The process for accomplishing this is described below:

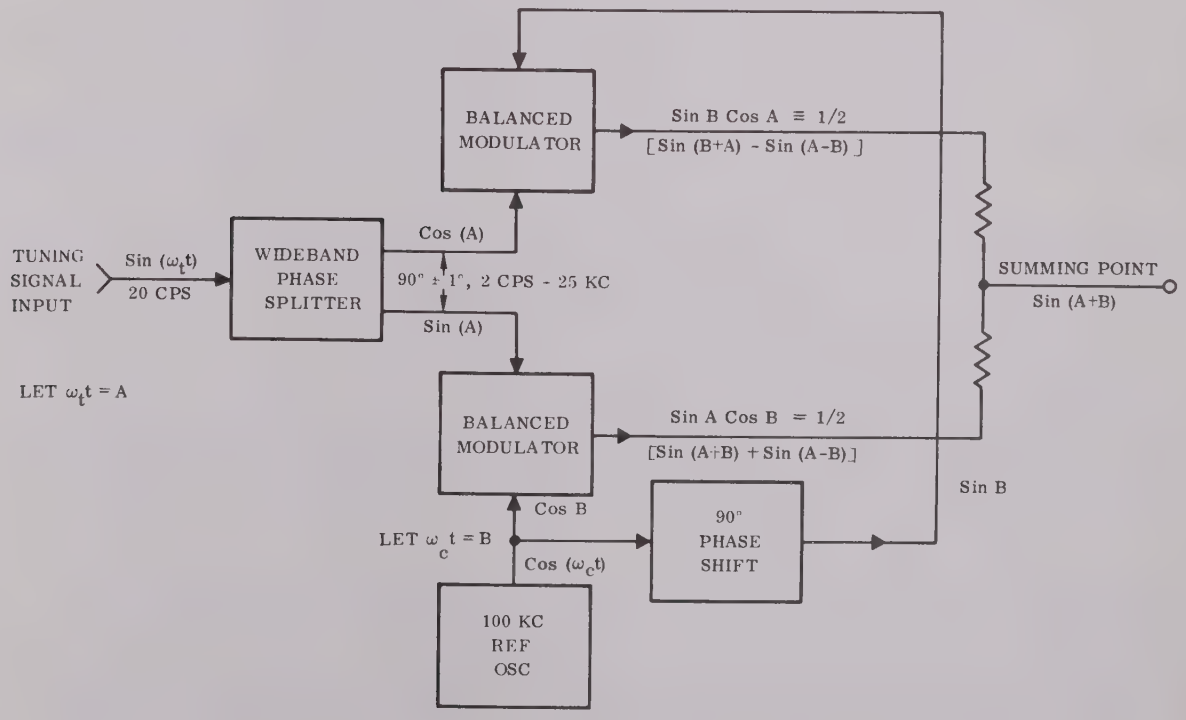


Figure 6. Carrier Converter

The tuning frequency is applied to a wide band phase shift network, producing two output signals equal in amplitude, but displaced in phase 90° with respect to each other. The outputs from the phase shifters are applied to two (2) balanced modulators where they modulate reference oscillator signals. The reference oscillator is also split into two (2) outputs that are 90° apart. The outputs from the balanced modulators are the sum and difference frequencies of the reference oscillator and the tuning frequency.

The modulator outputs are then linearily added together and the lower side band frequency is phase and amplitude cancelled, leaving only the sum of the input frequency plus the tuning frequency. Reference to figure 7 shows the trigonometric equations indicating how this is accomplished.

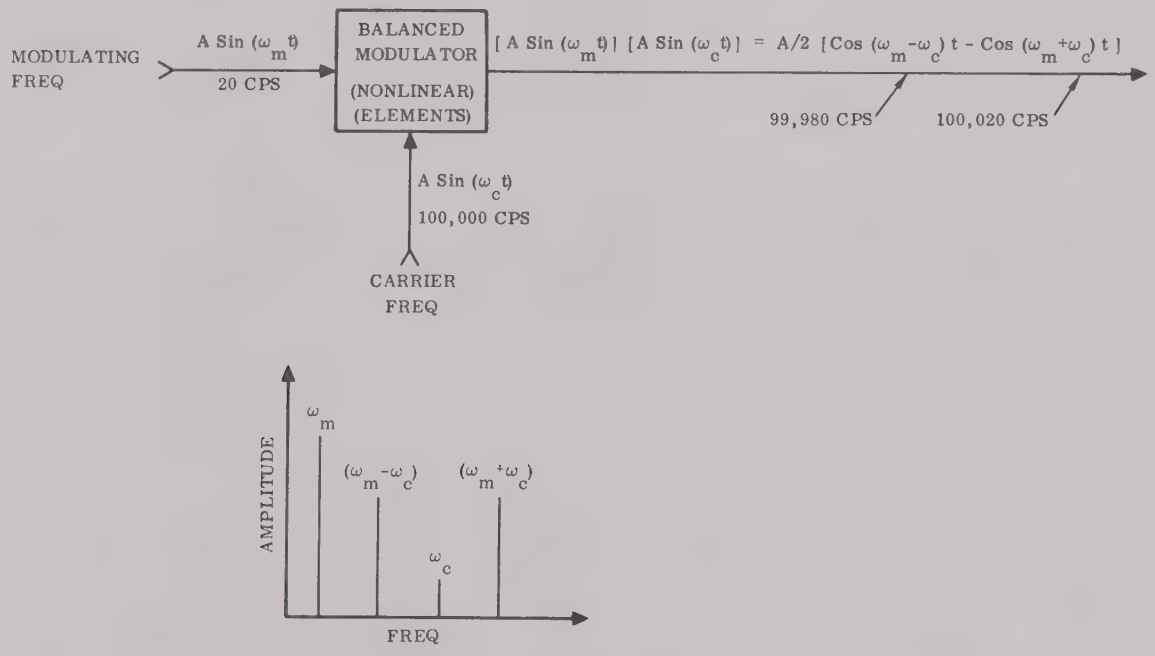


Figure 7. Balanced Modulator

A Word About Amplitude Modulation Theory:

Modulation is basically a process of multiplication.* To accomplish this process with simple analog devices involves the use of some non-linear element, such as diodes, vacuum tubes, varistors, etc.

The SD101A uses four (4) balanced modulators. The term "balanced" is used to denote a balancing or cancellation of the carrier frequency in the output of the modulator.

* A more thorough treatment of the subject can be found in any standard electronic engineering textbook.

As mentioned previously, modulation is basically a process of multiplication. Therefore, for illustration purposes, let us examine what occurs when two sine waves are modulated or multiplied in a balanced modulator:

Referring to the preceding figure, it is seen that two distortionless sine waves ideally multiplied together have a triognometric identity as shown, meaning that there are two (2) frequencies produced at the modulator output; i.e., the lower "sideband" frequency represented by the $(\omega_c - \omega_m)$ term in the trigonometric identity and the upper "sideband" frequency represented by the $(\omega_c + \omega_m)$ term.

The carrier frequency used in the SD101A is 100,000 CPS. The amplitudes of the side band signals on the output of a modulator are identical and proportional to the amplitude of the input signal amplitude, assuming that the amplitude of the carrier signal applied is constant.

In summary, when one signal is modulated by another, output frequencies are produced at the sum and difference of the two frequencies. If the carrier frequency is held constant in amplitude, the side band amplitudes are proportional to the input signal amplitude. If a complex wave is applied to a modulator, side band frequencies due to each of the signal frequency components are produced.

Figure 7 also shows an example of modulation of 100,000 CPS signal with a 20 CPS signal and the side band frequencies and illustrates graphically the distribution of the two side bands symmetrically about the carrier frequency ω_c.

Internal Calibration Circuit and Alignment of Reference Oscillator with Filter Center Frequencies:

Concept of the alignment procedure is seen by referring to figure 8a. The purpose of alignment is to adjust the filter center frequency to be centered at the tuning frequency. In concept this could be accomplished by tuning the filter with the same frequency as the data frequency. Since the center frequency of the pass band is supposed to be centered at the tuning frequency input, we could verify this by simply shifting the center frequency of the filter higher and lower in frequency with respect to the data frequency until the output from the filter reaches a peak. This concept is shown in figure 8a. Figure 8b shows the data frequency centered with the filter passband, and figure 8c shows the filter not aligned with the data signal.

Shifting the passband relative to the data signal is accomplished by shifting the frequency of the reference oscillator with respect to the center of the crystal filter passband. Therefore, the front panel adjustment labeled FREQ. is in effect shifting the center frequency of the passband relative to the tuning signal. Once the filter passband is set relative to the tuning frequency it will remain set over the frequency range.

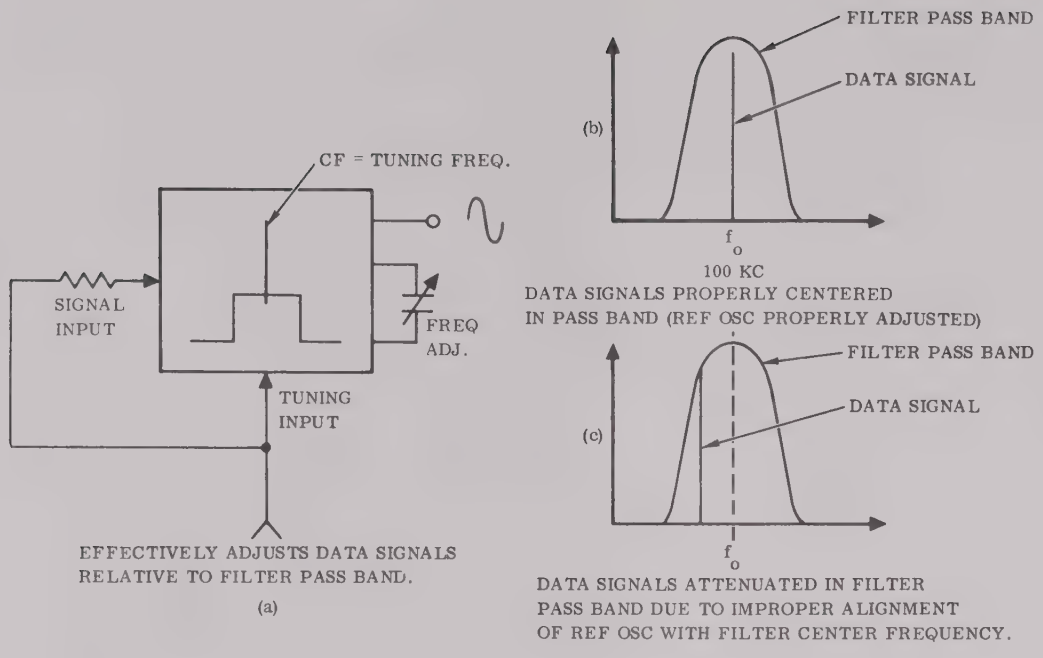


Figure 8. Alignment Procedure

From the above discussion, it is seen that it is desirable to minimize drift of the 100 KC filter center frequency relative to the reference oscillator frequency. To accomplish minimum drift on a long-term basis is the reason for the oven-controlled crystal filters and oven-controlled reference oscillator.

Shown in figure 9 is the practical circuit provided internally to not only adjust the center frequency of the filter, but apply a precise calibration reference signal to the input amplifier to set up and check the calibration of the instrument and any external readout devices.

When the RANGE switch is placed in the CAL position, the external tuning signal and signal inputs are disconnected from the unit. A portion of the 60 CPS filament voltage is fed into the tuning input and a 60 CPS square wave with a fundamental sine wave amplitude of 70 MV RMS is applied to the input amplifier. Adjusting the FREQ control for a peak aligns the filter with the tuning signal. Adjusting the filter CAL potentiometer for a meter reading of seven calibrates the unit.

3-2. CIRCUIT DESCRIPTION

A thorough understanding of the general theory and concept of operation, along with the following circuit description will help in the application of the instrument, as well as the potential trouble-shooting of the instrument.

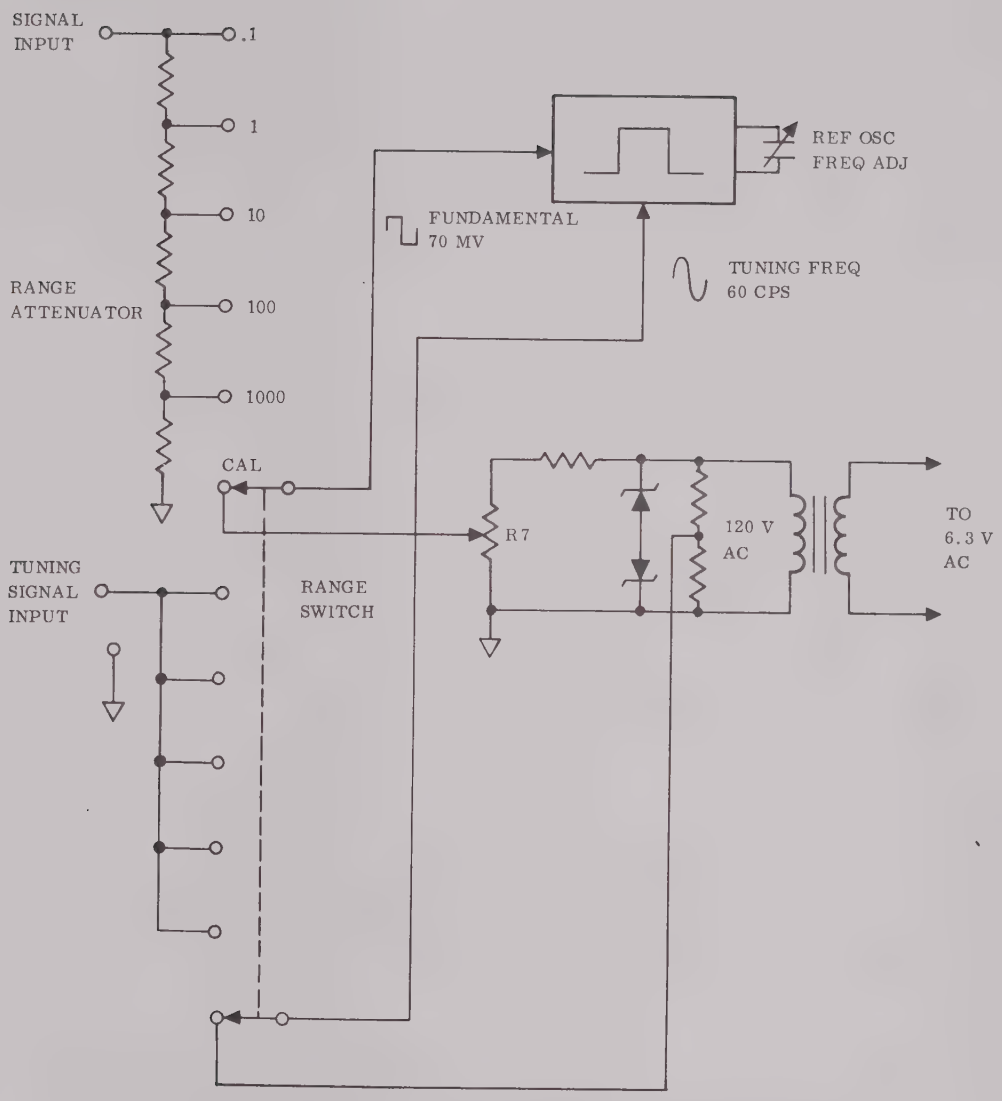


Figure 9. Internal Calibration

A. Filtering and Measurement Section

Range Switch (S1A, S1B)

The RANGE switch is a two-deck switch with two poles and six positions per deck. The input signal attenuator (S1A) is a one-megohm voltage divider with five positions for input signal attenuation ranges and the sixth position connects the 60 CPS reference voltage to the input amplifier. The second pole on S1A is used to disconnect the external tuning signal from the tuning signal input and apply an internal 60 CPS tuning signal. The second switch deck is used to activate the calibration signal circuit. This switching is done to eliminate 60 CPS hum from coupling into the input amplifier when the calibration circuits are not in use.

Calibration Circuit

Calibration circuit is made up of R6, R7, R8, R9, T1 and CR1. T1 is a filament transformer operated in reverse; i.e., the secondary is excited with 6.3V AC from the power supply filament source, thus producing 120 VAC at the primary. R8 is a current limiting resistor for the back-to-back reference diode, CR1. CR1 clips the 120V signal to a reference level of 12V peak-to-peak. R6 and R7 form a voltage divider to drop the 12V down to a 70 MV fundamental (equivalent sinusoidal amplitude). R7 is the CAL adjust potentiometer.

Input Amplifier (V1, V2, V3)

The input amplifier is a two-stage voltage feedback amplifier with a cathode follower output providing the driving signals to the signal modulator. The GAIN control varies the feedback around the amplifier and is set up to give an adjustment range of 18 DB. CR4 is used to prevent blocking and provides rapid overload recovery. The input amplifier has a fixed closed loop gain of 100 in the CALIBRATED position and will handle crest factors (peak/RMS) of 4 to 1. The gain is fixed at 100 by means of an internal potentiometer, R19, located between V2 and V3.

Signal Modulator (T2, C82, CR2A and B, R23, R24, R21)

The output of the input amplifier is connected to the signal modulator. The modulator is a shunt-type carrier balanced modulator. The transformer is specially constructed to minimize reactive unbalance, and the diode pair (CR2A and B) are matched in characteristics to minimize carrier leak. C82 is an adjustment to allow further reactance balancing. The primary of T2 is driven by V16, which is connected to the carrier converter output. The output of the signal modulator will be a half wave suppressed carrier double sideband signal.

Filter Driver (V4)

The output of the signal modulator goes to V4 which is a cathode follower used to provide impedance matching and isolation between the modulator and the crystal filters. A 3K resistor in series with the input to the filter provides proper input termination for the filter.

Filter Selector (S2A)

The FILTER selector switch is a four-position switch for selecting the desired filter bandwidth, manually or automatically, and to by-pass the SD101A altogether.

Crystal Filters

The crystal filters are multi-section crystal lattice filters, providing extremely narrow skirts. The filters have a shape factor defined as the ratio of the 60 DB bandwidth divided by the 3 DB bandwidth of nominally 4/1. This shape factor is the same on all

standard Spectral Dynamics' filters. Special bandwidths and shape factors can be supplied. The filters operate at a center frequency of 100 KC and require 3K resistive input and output termination. Signal sideband components falling within the filter bandwidth are passed through to potentiometers R28 and R29. R28 and R29 are used to equalize the relative insertion loss between the filters in the SD101A and additionally are used to establish the proper gain levels in the following amplifier stages. The 7.5K resistors shunting the potentiometers give proper load impedance to the crystal filters.

Tuned Amplifier (V6, V7)

This amplifier is used to remove spurious filter outputs and is a tuned, two-stage voltage feedback amplifier. R262 is used to adjust the gain of the stage to approximately 300.

Multiplier (R43 - R47)

The output of the Tuned Amplifier is routed to the Phase Adjust circuit that in turn drives the demodulator driver V5. The tuned amplifier output is also routed to the MULTIPLIER attenuator where the sensitivity of the meter and recorder circuits are controlled. The multiplier allows the meter to read levels 55 to 60 DB below a large input signal component.

Phase Adjust (T9, S8, C103, R261)

The phase adjust circuit provides a means of normalizing the input to output phase or the Filtered Signal Output phase relative to that of another unit such as another SD101A or SD1012 Tracking Filter. S8 is used to reverse the transformer (T9) leads thus providing a 180° phase shift. R261 is used to adjust the phase over a range of approximately 115 degrees.

Meter and Recorder Circuits (V8, V9, V10, M1)

The output of the multiplier is connected to a nuvistor tetrode (V8) to minimize capacitive loading of the multiplier. The tetrode is the input stage of a two-stage voltage feedback amplifier with a cathode follower output. The cathode follower drives the meter rectifier bridge and a rectifier (CR6) providing the DC analog output. The 100 KC signal level at the cathode follower output is approximately 20V peak-to-peak. Voltage feedback is derived from the cathode follower output for gain stabilization. R53 is the feedback resistor used to adjust the amplifier for a nominal gain of 80.

Recorder Output

The output of CR6 is connected to a smoothing filter comprised of C22, R59, and C23, with the output of the smoothing filter connected to an output level adjustment, R60. The output presents a variable output impedance to a load and will provide at least 1V DC into a 100K load for full-scale meter deflection. Since rectification of a 100 KC

signal is accomplished, short-time constant filtering is used giving the DC output rapid response with little ripple even at low input frequencies.

Demodulator-Demodulator Driver (V5)

The output of the tuned amplifier is connected via the Phase Adjust circuit to V5 which is a cathode follower used to drive one input of a ring demodulator. The other input to the demodulator is supplied from the carrier converter coupled to the demodulator through V16. The carrier converter output frequency varies from 100,002 CPS to 125,000 CPS, corresponding to the tuning frequency input. The output from the tuned amplifier represents the heterodyned filtered signal and combined with the carrier converter frequency in the demodulator produces an output which is the sum and difference frequencies between the two signals and an amplitude proportional to the heterodyned filtered signal. The lower sideband or beat frequency will be a signal that can vary in frequency from 2 CPS to 25 KC and the sum of the two will be a frequency varying from 200,002 to 225,000 KC. The amplitude of the signal component is proportional to the filtered signal component.

The demodulator output is then connected to a low pass filter network made up of L1, L2, L3, C1, C2, C3, C4, and R82. The low pass filter is used to remove the upper sideband component and has a nominal cutoff frequency of 30 KC, so that it will pass the signal components from 2 CPS as high as 30 KC with little attenuation and reject the high frequency components from the modulator. The output of the low pass filter is then connected into the filtered signal output amplifier.

Filtered Signal Output Amplifier (V17, V18 and V49)

The filtered signal output amplifier is a two-stage voltage feedback amplifier, with a cathode follower output coupled to the filtered signal output terminals. The amplifier has the capability of driving 10V RMS into a 10K load for full signal input. The output from the cathode follower (V49) is coupled to the output terminals through C101, a 50 mfd. capacitor. When connecting loads to the output of the SD101A, it must be kept in mind that best frequency response will be obtained with high impedance load. R253 sets the voltage gain of the amplifier to approximately 300.

B. Carrier Converter Section

The tuning signal is connected into the unit through a 100K potentiometer R90. The potentiometer is used to adjust the level of the tuning signal for proper circuit operation. The tuning signal is then routed to the RANGE control switch to facilitate application of a fixed internal tuning signal, making it unnecessary to disturb the setting of the tuning amplitude adjustment, during the calibration procedure. The tuning signal is next fed through the tuning signal amplifier which isolates the external circuitry from the printed circuit board.

Wide Band Phase Shifter

The wide band phase shifter consists of two printed circuit cards with the necessary tubes and components mounted on it and identified as the upper and lower printed circuit card. The cards are arbitrarily identified LOWER and UPPER for use as a guide for the mo ing and setting up of the cards.

The theory of operation can be described as follows: The phase shifter is made up of a combination of half lattice all pass sections. The upper board produces a relatively smooth phase shift versus frequency curve and the lower board produces the same characteristic phase shift only displaced by 90° (figure 10).

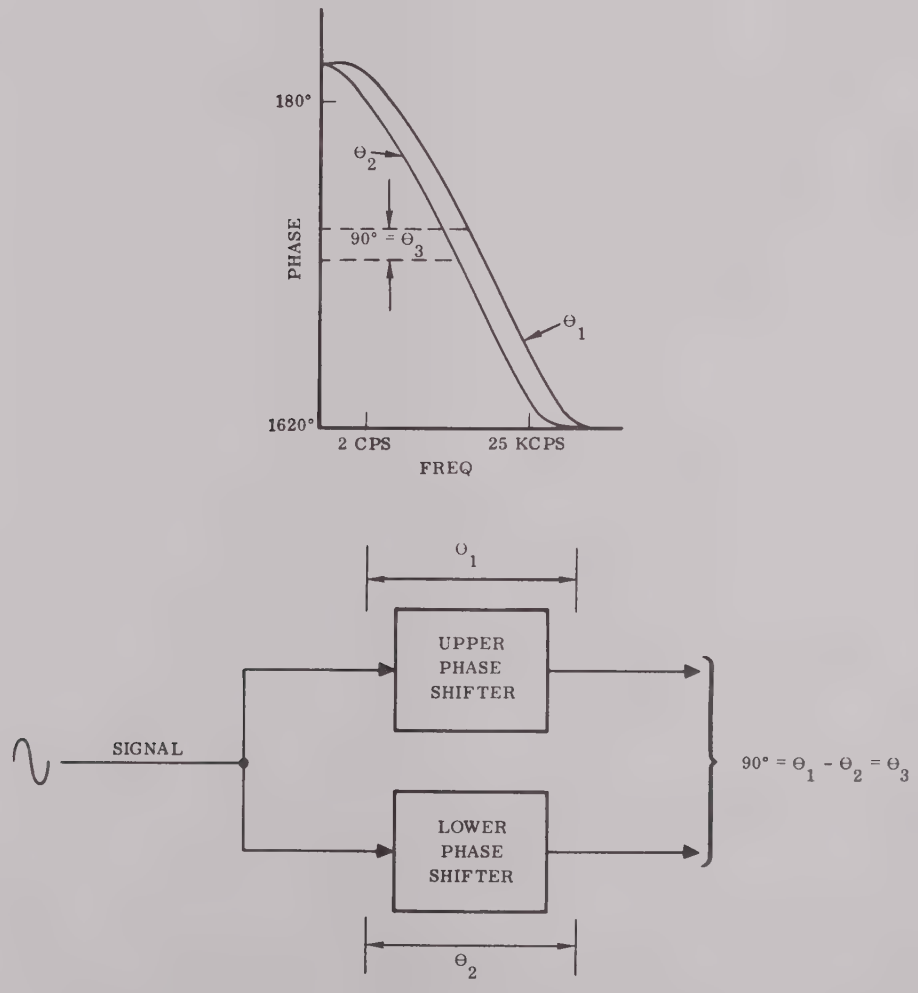


Figure 10. Wideband Phase Shifter

The output of the boards will be two signals equal in amplitude but displaced by 90° over the operating frequency range. A thorough treatment of the subject can be found in the following references:

1. D. Norgaard - The Phase-Shift Method of Single Sideband Signal Generation - Proc. IRE, December, 1956.
2. R. B. Dome - Wideband Phase Shift Networks - Electronics, Vol 19, Pages 112-115, December, 1946.

The outputs of the wideband phase shifter are connected to two modulators.

Carrier Modulators

The carrier signals are applied to the balanced ring modulators from the reference oscillator circuits. The reference oscillator circuits drive the modulators with 100 kHz signals shifted 90°. The output of the modulators are then linearily summed in A12R7, Carrier Amplitude Balance adjustment located on printed circuit card A12 - Assembly 10568-1.

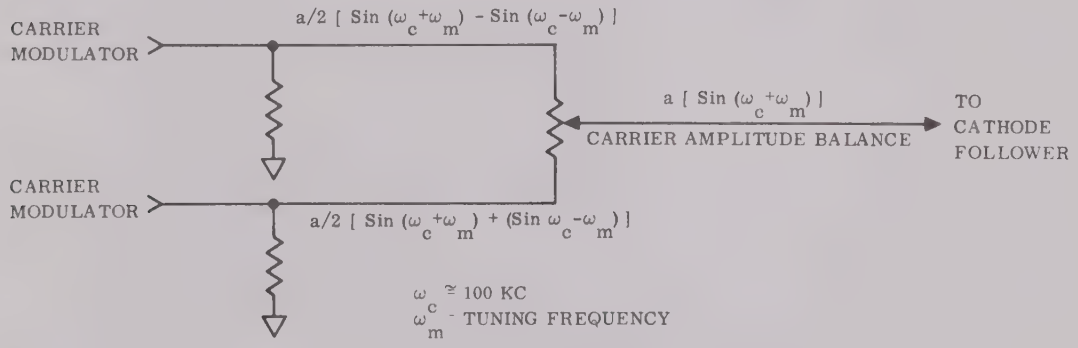

CARRIER MODULATOR
a/2 [Sin (ωc+ωm) - Sin (ωc-ωm)]
a [Sin (ωc+ωm)]
CARRIER AMPLITUDE BALANCE
TO CATHODE FOLLOWER
CARRIER MODULATOR
a/2 [Sin (ωc+ωm) + (Sin ωc-ωm)]
ωc ≅ 100 KC
ωm - TUNING FREQUENCY
ADDITION OF MODULATOR OUTPUTS TO GIVE UPPER SIDEBAND

Figure 11. Upper Sideband

The addition of the two signals results in the upper sideband amplitude adding together and the lower sideband amplitudes adding out (figure 11).

Bandpass Filter (100 - 150 KC)

The output of the adjusting potentiometer R199 is connected to V40 which is a cathode follower amplifier used to drive a bandpass filter. The bandpass filter is used to remove spurious modulation components and provide a clean upper sideband signal to the carrier amplifier.

Carrier Amplifier (V41, V42)

The carrier amplifier amplifies the upper sideband signal to a suitable level for driving the signal modulator and demodulator. The output of the carrier amplifier is routed to the External, Internal Carrier switch. With the EXT/INT switch in the INT position, the carrier amplifier output is connected to the signal modulator/demodulator driver (V16). With the switch in the EXT position, the B+ supplied to the carrier converter section is disconnected and an external carrier signal can be connected into the connector marked EXT CARRIER INPUT. Driving the modulators from an external source is desirable when using two or more SD101A's slaved together.

Reference Oscillator-Phase Shifter-Carrier Modulator Drivers

The reference oscillator consists of V11, V12 and the plug-in reference oscillator crystal and oven. The oscillator is a Pierce-type. The frequency control C28, is used to adjust the frequency of the reference oscillator over a range of approximately ±15 CPS. The stability of the oscillator is ±.25 CPS and is maintained over long periods of time due to the oven-controlled crystal.

The output amplitude of the oscillator is controlled by C25 and C90. The oscillator output is connected to V14. V14 is a paraphase phase-shift amplifier with the phase shift determined by the R. C. half lattice output network. The lattice output is connected to a modulator driver, V15. The R.C. combination, adjustable with R73, is adjusted to produce a 90° phase shift between the output of V13 and the output of V15. The signal appearing across R72 is used to drive V13.

Power Supply

The power supply module provides 125 milliamps at 150 VDC, ripple 1 MV RMS (MAX.) and regulation of 0.05%. With the POWER switch on STBY the filament voltage is applied to the tubes and heater voltage is applied to the filter and oscillator ovens.

SD101A DYNAMIC ANALYZER - OPTIMUM PERFORMANCE CHECKS

1. For the following checks, operate the SD101A from a Variac®-type power source set initially for 115 volts rms.

2. Install 5 Hz or 10 Hz crystal filter(s) and allow at least 45 minutes for the crystal ovens to stabilize.

> NOTE
>
> The SD101A contains mercury-wetted relays. Operation in other than its normal upright position may produce a false indication that the unit is inoperative. However, for troubleshooting or calibration purposes, it may be gently positioned on its side and operated satisfactorily, provided the mercury within the relays has not shifted.

3. From a Model SD104A Sweep Oscillator, connect the constant amplitude sine wave output and the variable sine wave output to the TUNING INPUT and SIGNAL INPUT, respectively, of the Model SD101A.

4. Set the SD104A for 100 Hz, with a signal input level to the SD101A of 1 volt rms. Adjust the TUNING INPUT control on the SD101A for a mid-scale indication on the TUNING AMPLITUDE meter.

5. Rotate the front panel GAIN control counter clockwise to the CALIBRATED detent position. Note: On early SD101A units that do not have the detent position, verify the correct gain setting of the Input Amplifier per the instruction manual.

6. Calibrate the SD101A in the normal manner (RANGE and MULTIPLIER switches to CAL, meter to "7", etc.). Return the RANGE and MULTIPLIER switches to the 1.0 volt, X1, positions, respectively.

7. If the SD101A signal meter does not indicate 1 volt, ±2%, adjust the appropriate FILTER - CAL control as required. Rotate the RANGE and MULTIPLIER switches to their CAL positions and adjust potentiometer R7 (top of chassis, left rear) for a meter indication of "7". Return the RANGE and MULTIPLIER switches to the 1.0 volt, X1 positions, respectively.

8. Connect an oscilloscope and true-rms meter to the FILTERED OUTPUT (FSO) terminals. While viewing the FSO waveform on the scope, turn the FSO level control fully clockwise and note that the amplitude is at least 10 volts rms. Readjust the FSO output level for 1.0 volt rms and then slowly turn the FREQ ADJ control while observing the scope. Throughout the change in the FSO amplitude, the waveform should remain a clean sine wave. Distortion of the waveform indicates that the carrier converter is not balanced or has failed. Leave the FREQ ADJ control in a "peaked" position.

9. Reduce the input line voltage to 105 volts rms and note that the FSO and front panel signal meter indications do not decrease by more than 3%. A decrease in excess of 3% is an indication that one or more tubes need replacement. Gently place the unit on its side and first check the power supply as follows: With the line voltage reduced to 105 volts rms, the power supply should be regulating firmly at 150 volts dc, with ripple less than 5 mv p-p. If not, replace power supply tubes as necessary and check capacitor C4 for possible replacement.

   Assuming proper operation of the power supply, next check the carrier converter circuitry as follows: Measure the carrier amplitude at rear BNC connector J11 (CARRIER SIG OUT) for 50 to 70 volts p-p. Reducing the line voltage from 115 to 105 volts rms should cause no more than 3-5 volts p-p decrease in the carrier amplitude, and in any case, the amplitude should not fall below 50 volts p-p. If necessary, substitute new tubes for V11 and V12 and then V40, V41 and V42. While varying the line voltage between 105 and 115 volts rms, change tubes as required in the phase shifter circuit cards (A4 and A5) to minimize the changes in signal level at TP14 and TP15.

   If the output amplitude and signal meter indications are still in excess of tolerance, methodically substitute tubes throughout the remainder of the instrument, starting with the input amplifier and then the filter driver, tuned amplifier, meter amplifier, demodulator driver and FSO amplifier, in that order. Restore the input line voltage to 115 volts rms.

10. Remove the SD104A variable sine wave signal connected to the SIGNAL INPUT terminal. Using a second audio oscillator, apply 1 volt rms, 100 Hz, to the SIGNAL INPUT terminals. Tune the SD104A to approximately 50 Hz and turn the SD101A MULTIPLIER switch to the 0.01 position. Slowly tune the SD104A for a peak indication on the SD101A signal meter and then detune it slightly for a noticeable "beat" indication. The meter indication should be less than the 6 dB mark or more than 44 dB down from full scale. If not, the carrier converter balance adjustments should be performed per paragraph 4-8. of the instruction manual.

    Tune the SD104A to approximately 33 Hz and repeat the preceding step for meter indication of at least 44 dB down. If necessary, adjust the carrier amplitude balance and the oscillator phase controls per paragraph 4-8. of the instruction manual.

    Repeat the two preceding steps, as necessary, for signal meter indications at least 44 dB down at both 50 and 33 Hz.

11. Restore the variable sine wave signal (1 volt rms, 100 Hz) to the SIGNAL INPUT terminals on the SD101A.

    While observing the signal meter and the true-rms meter indications, sweep the frequency of the SD104A from 10 Hz to 10 kHz. The signal meter should not vary more than ±2% and the FSO variation should be less than ±0.25 dB.

11. (Cont'd)

Decrease the amplitude of the input signal to the SD101A by 30 dB and recheck the frequency response. If the FSO varies in excess of ±0.5 dB, the most probable cause is that the phase shifter circuit cards are out of calibration and should be returned to the factory for repair and calibration.

12. Restore the SD101A input signal to 1 volt rms, 100 Hz and note the indications on the signal meter and the true-rms meter. Turn the RANGE and MULTIPLIER switches to the 100 volts and X0.01 positions, respectively. Increase the sensitivity of the true-rms meter by 40 dB and note that both meters indicate within ±1 dB of the preceding indications.

13. Remove the input signal and, within 10 seconds, the signal meter indication should decrease to less than the "0" dB mark, or 50 dB down from full scale. The FSO amplitude should be at least 50 dB below the full scale level noted in step 12. above. If the FSO residual signal level is too high, it may be corrected by replacing V17, as heater-to-cathode leakage will often cause the FSO level to be affected by abnormal line noise.

14. Set the RANGE and MULTIPLIER switches to the 1.0 volt and X1 positions, respectively. Connect a 100 kΩ resistor across the front panel RECORDER OUTPUT terminals and then adjust the recorder output for 1 Vdc, as measured with a digital voltmeter. Turn the RANGE switch to the 100 volts position and note that the recorder output level decreases by 40 dB, ±0.5 dB (approximately 9.5 to 10.7 mV). If not, adjust R269 (under the chassis adjacent to V10).

15. Reduce the input signal to 100 mV rms and place the RANGE switch in the 0.1 volt position. Adjust the input signal level as required for full scale indication on the signal meter and adjust the RECORDER OUTPUT for 1 Vdc.

Increase the input signal to 200 mV rms (6 dB increase) and the recorder output level should then be 2 volts dc, ±0.5 dB (roughly 1.9 to 2.1 Vdc). This demonstrates the overload capability of the recorder output circuitry.

16. Restore the input signal level to 100 mV and set the FILTERED OUTPUT level for 1V rms. Increase the input signal to 280 mV rms (9 dB increase) and the FSO level should increase by 9 dB, ±0.5 dB, or approximately 2.65 to 3 volts. This demonstrates the overload capability of the FSO circuitry and the Input Amplifier.

17. A Model SD101A that successfully meets the requirements of the preceding performance checks can be considered to be operating normally. No further calibration is necessary unless the unit will be used for very demanding operation over a wide dynamic range.

SECTION IV

MAINTENANCE

4-1. GENERAL.

The various assemblies in the analyzer, with major circuit locations are shown in figures 12 and 13. Viewing the bottom of the analyzer it is seen that the unit is comprised of four major assemblies which are designated: (1) Low Frequency; (2) High Frequency; (3) Carrier Converter; (4) Power Supply. The wideband phase shift networks are plug-in assemblies and are shown in figure 12, Item 3. The general location of specific circuits may be found by referring to figures 12 and 13.

4-2. TEST POINTS.

When trouble shooting and aligning the SD101A there are test points referenced on the Block Diagram and Schematic. These test points may be physically located by referring to figure 14. Waveforms and voltage levels at each corresponding test point are shown in the latter part of this section.

4-3. REPAIR AND MAINTENANCE.

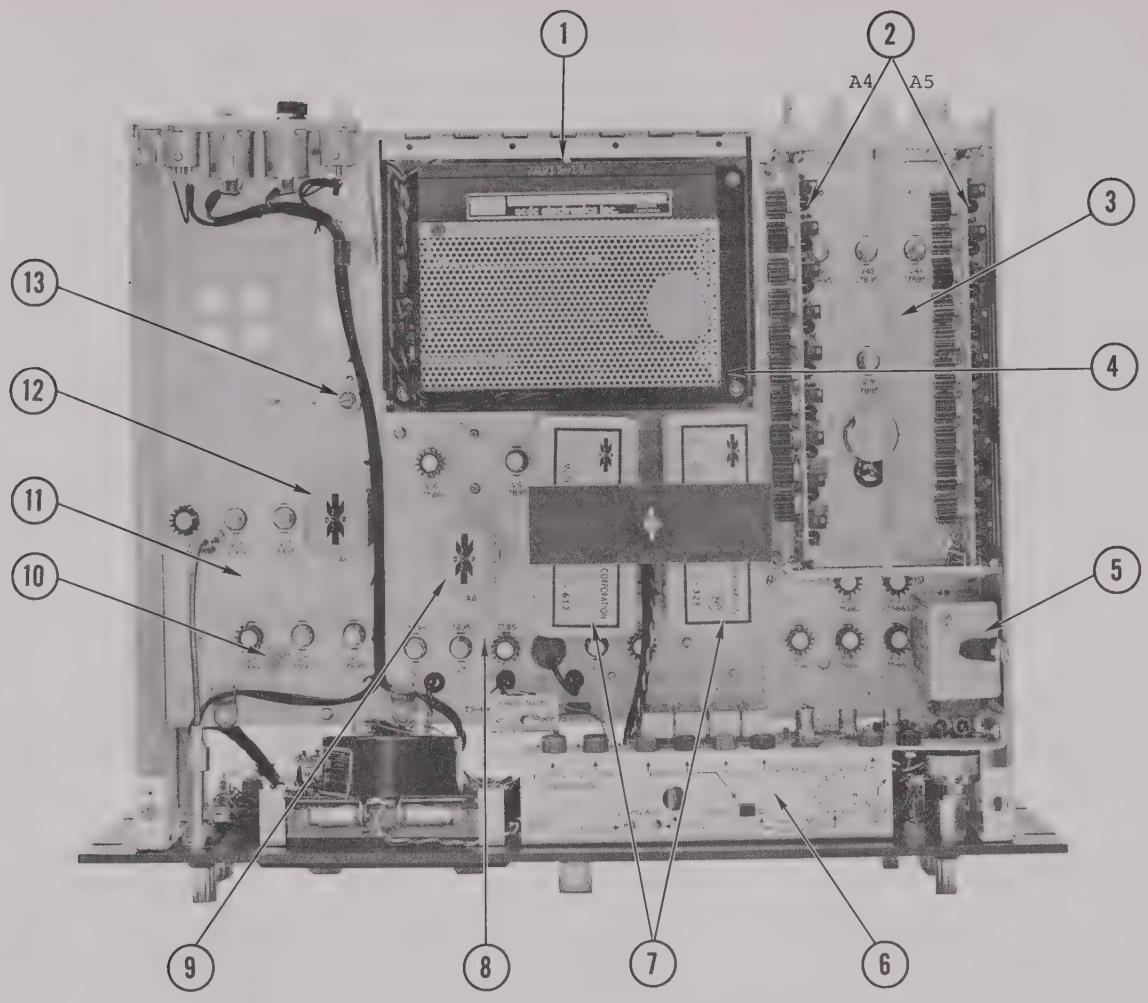
Repair and maintenance of all circuits can be accomplished by the user with the following exceptions:

1. Wideband Phase Shifters (figures 15 and 16)

Repair by the user of the circuits on the plug-in printed circuit boards should be limited to replacement of tubes, repair of broken leads and replacement of any of the 1/4 watt, 5%, 1000Ω resistors. Do not disturb the factory adjustments or precision components. If boards are in need of recalibration and adjustments (Ref. Item 5b Trouble Shooting Guide) they should be returned to the factory. Return of items to the factory is governed by the paragraphs Warranty and Shipping found in the preface of this manual.

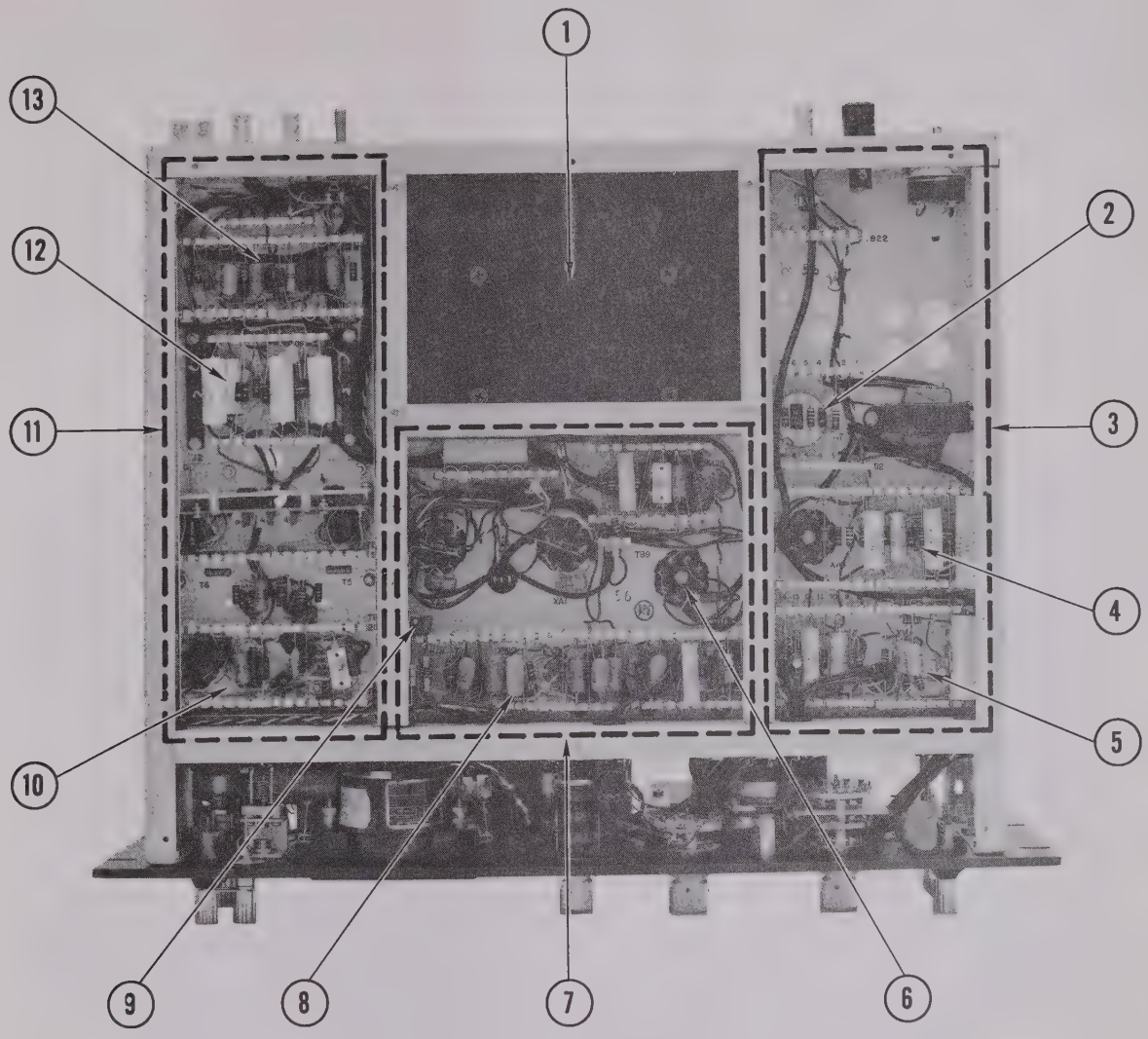
2. Crystal Filters

Due to the complexity of the crystal filters, repair should be performed only by the factory. Normally, the filters will perform indefinitely without maintenance or repair. The most common failure encountered is the malfunction of the thermostat controlling the oven heater. Thermostat failure is indicated by excessive shift in center frequency showing up as an apparent change in SD101A gain. Insertion-loss of the filters becomes very high. Occasionally, a filter will be dropped or mishandled which can result in damage to the crystals. If a filter requires repair, return it to the factory along



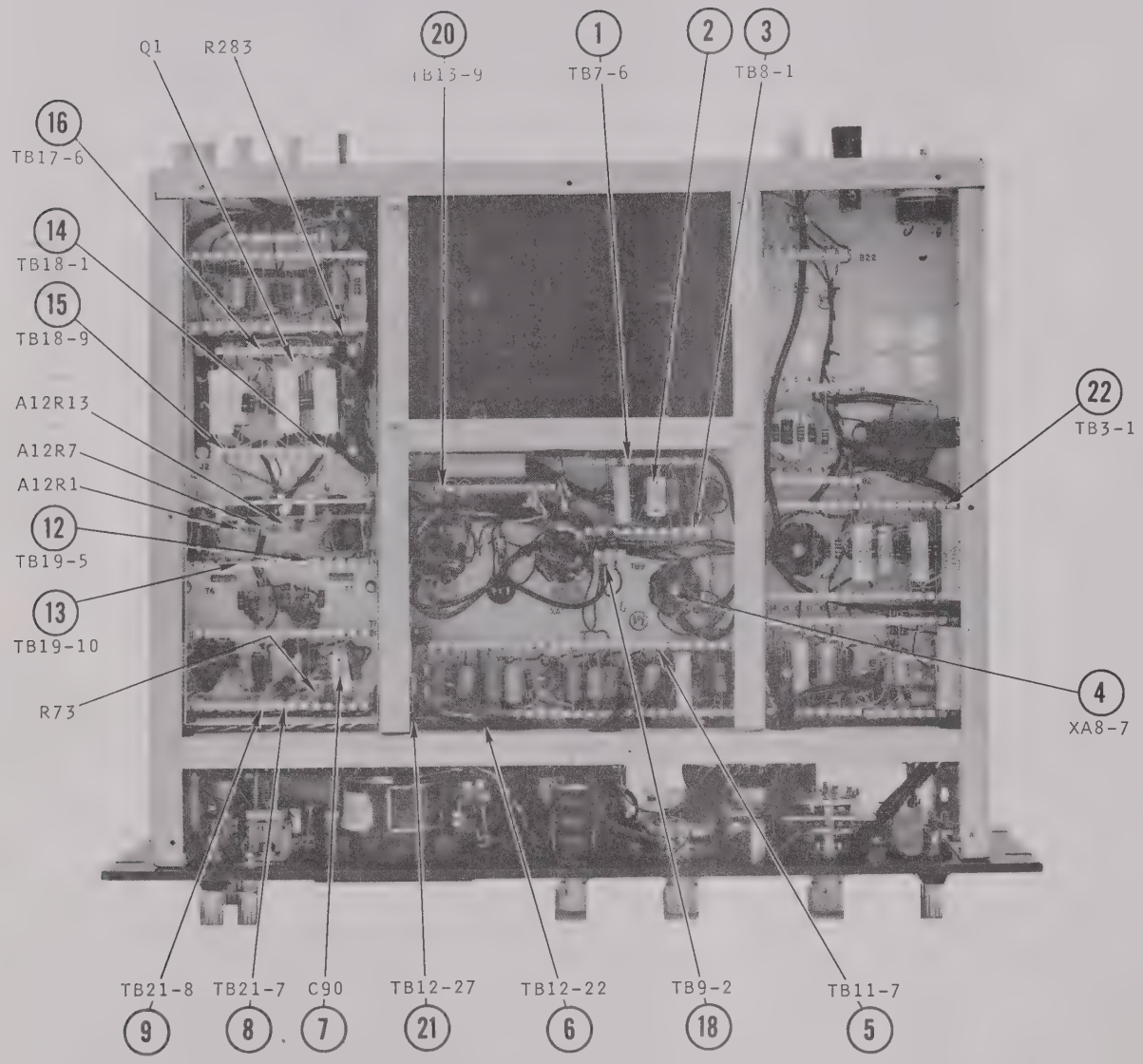
1 POWER SUPPLY MODULE (A7)
2 WIDE BAND PHASE SHIFT ASSEMBLIES (A4 UPPER - A5 LOWER)
3 CARRIER CONVERTER SECTION
4 B+ LEVEL ADJUSTMENT
5 100 kHz CRYSTAL OVEN ASSEMBLY (A3)
6 SD21 AUTOMATIC BANDWIDTH SWITCHING ADAPTER (A10)
7 PLUG-IN BANDPASS FILTERS (A1 & A2)
8 HIGH FREQUENCY SECTION
9 PLUG-IN DEMODULATOR ASSEMBLY (A8)
10 CALIBRATED GAIN CONTROL (R19)
11 LOW FREQUENCY SECTION
12 PLUG-IN 30 kHz LOW-PASS FILTER ASSEMBLY (A6)
13 REFERENCE CALIBRATION LEVEL ADJUSTMENT (R7)

Figure 12. Top Chassis View



1 POWER SUPPLY MODULE (Bottom side)
2 60 Hz CALIBRATION CIRCUIT (INTERNAL CAL REFERENCE)
3 LOW FREQUENCY SECTION
4 FILTERED SIGNAL OUTPUT CIRCUIT (FSO)
5 INPUT AMPLIFIER CIRCUIT
6 DEMODULATOR CIRCUIT
7 HIGH FREQUENCY SECTION
8 TUNED AMPLIFIER & METER AMPLIFIER CIRCUIT
9 DC OUTPUT LINEARITY ADJUST (R269)
10 100 kHz REFERENCE OSCILLATOR CIRCUIT
11 CARRIER CONVERTER SECTION
12 TUNING SIGNAL INPUT AMPLIFIER
13 CARRIER SIDEBAND AMPLIFIER AND FILTER

Figure 13. Bottom Chassis View



NOTE: ENCIRCLED NUMBERS CORRESPOND TO TEST POINT DESIGNATIONS ON THE SCHEMATIC, DWG. 10101.

Figure 14. Test Points & Internal Adjustments

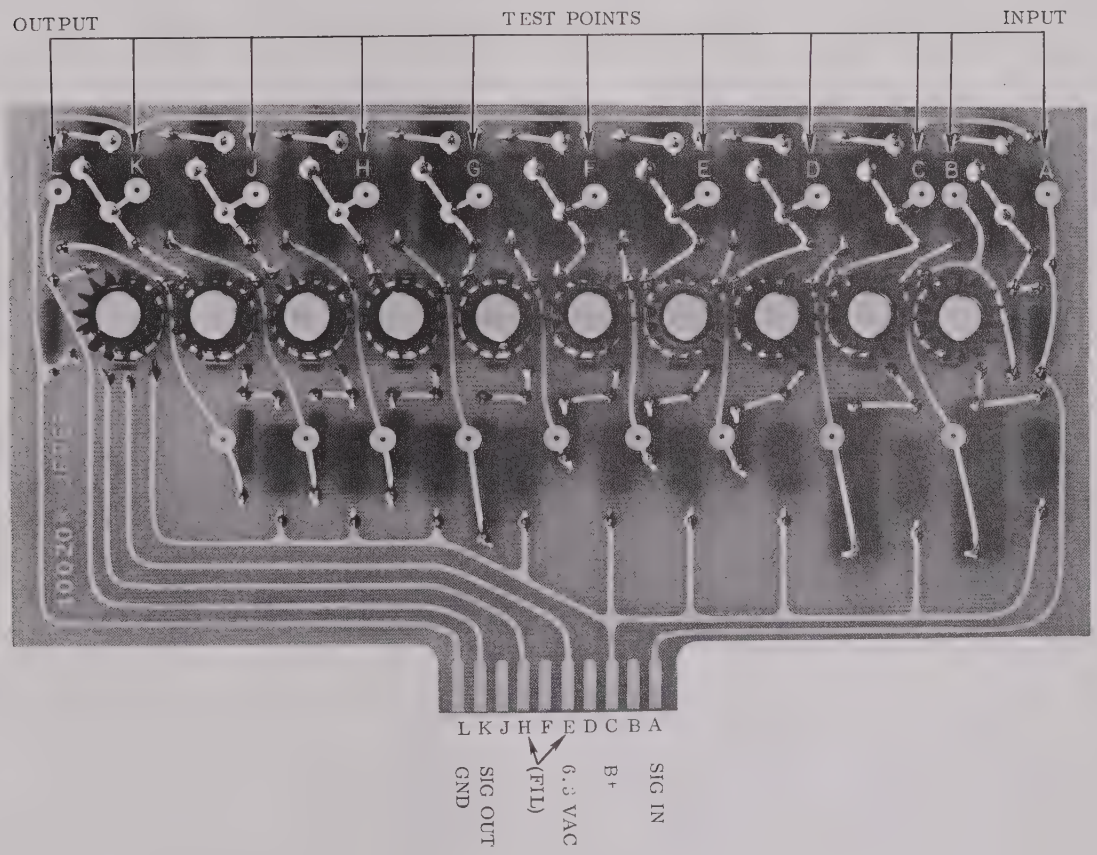


Figure 15. Wideband Phase Shift Circuit Board - Layout and Test Points

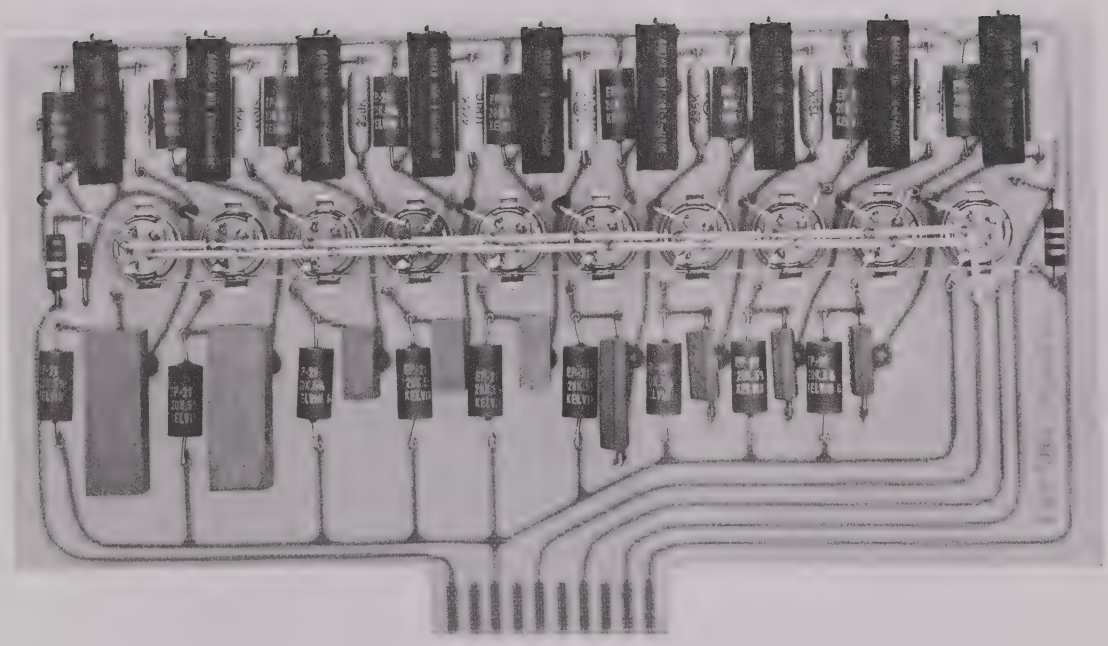
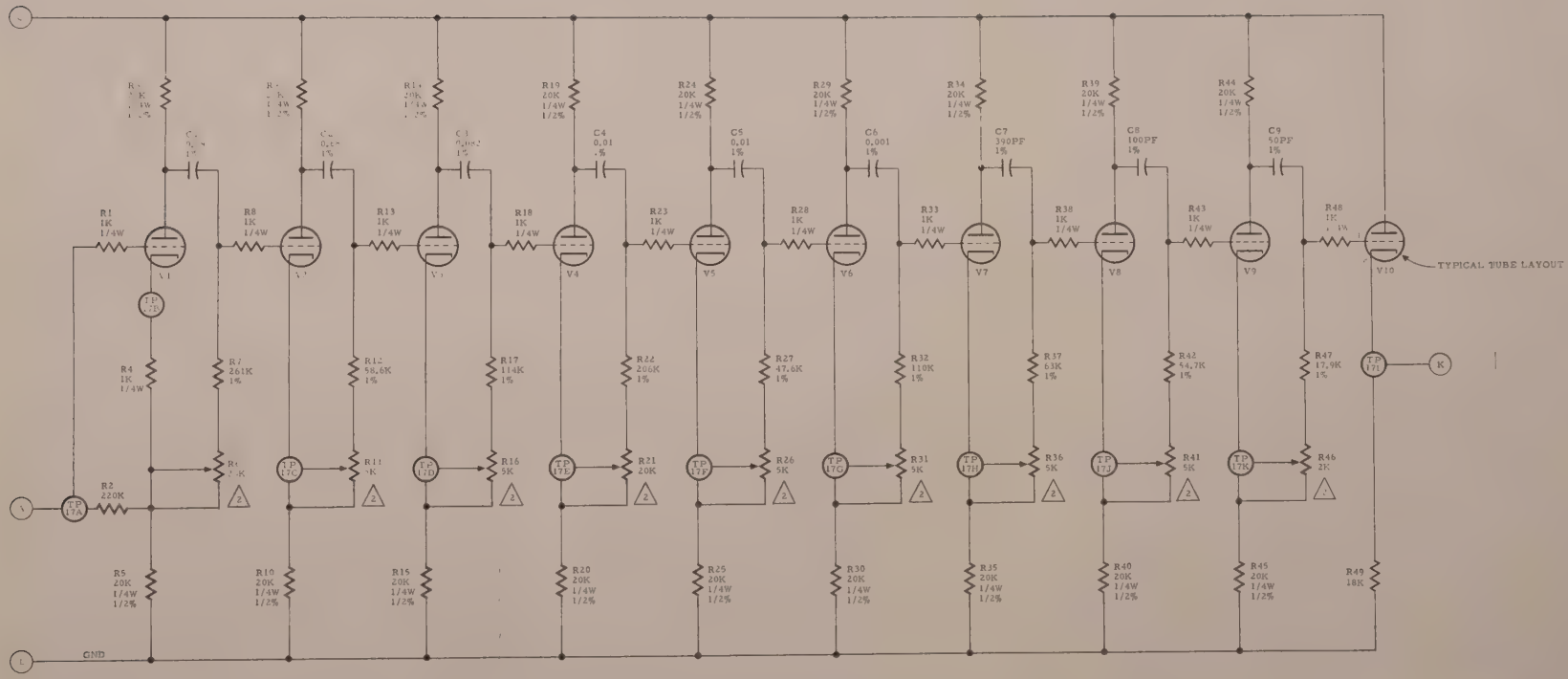
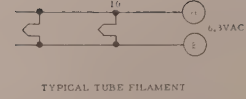


Figure 16. Printed Circuit Board (Component Side)





TYPICAL TUBE FILAMENT

NOTES:

1. RESISTOR VALUES IN OHMS, @ 1/2W, 5%, AND CAPACITOR VALUES IN MICROFARADS, @ 200V, UNLESS OTHERWISE INDICATED.
2. FACTORY ADJUST WITH OPTIMUM VALUE SHOWN.
3. ALL TUBES 7895 NUVISTORS.
4. HIGHEST REFERENCE DESIGNATORS USED:
   C9 L R49 TP17L V10

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SPECTRAL DYNAMICS CORPORATION OF SAN DIEGO

SCHEMATIC - WIDE BAND PHASE SHIFTER (LOWER) ASSEMBLY 10026

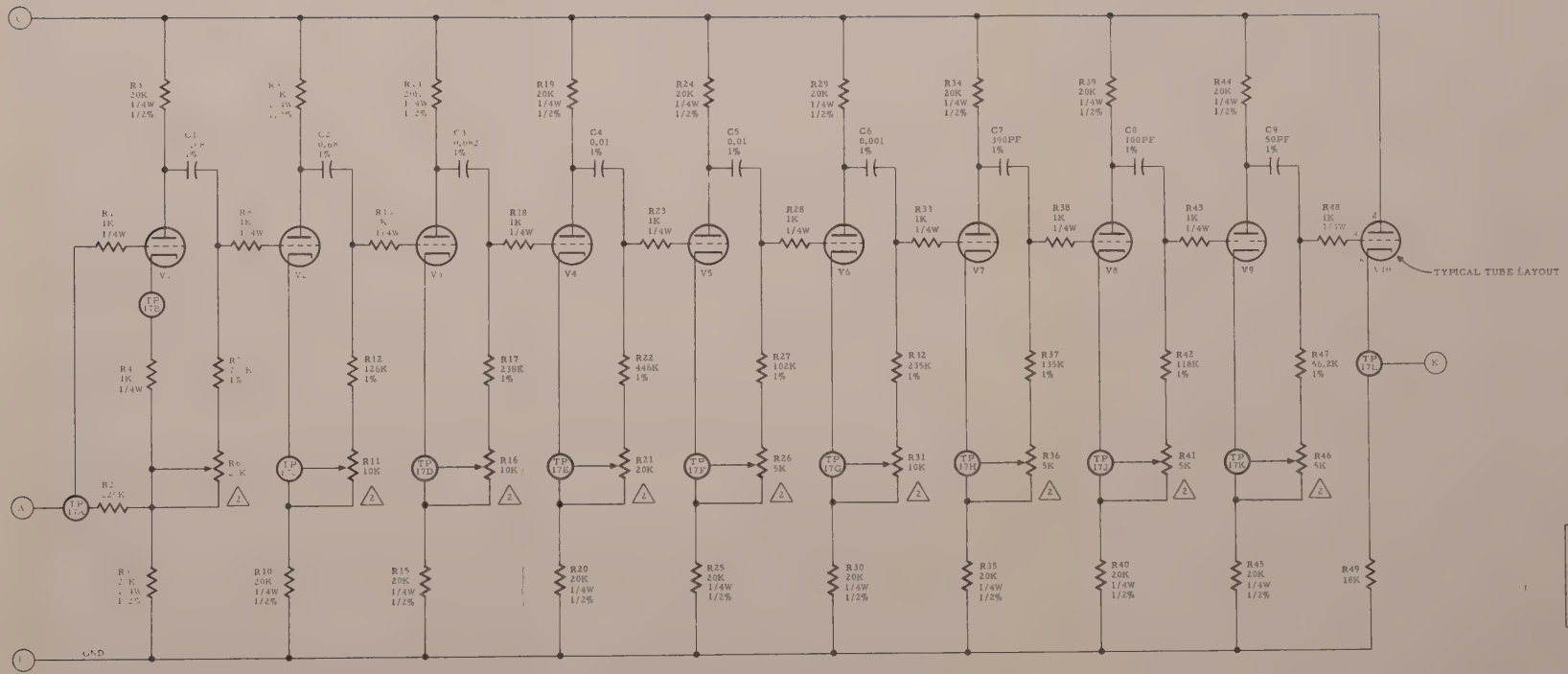
DRAWN R. C.
APPROVED R. PETRO
DATE 30 JULY 1965

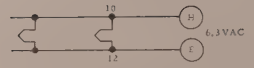
10241 A

SHEET 1 OF 1

Figure 16b. Schematic - Wideband Phase Shifter (Lower)

REVISIONS		
ENG	DESCRIPTION	DATE
A	Redrawn for publication.	[illegible]





TYPICAL TUBE FILAMENT

NOTES:

1. RESISTOR VALUES IN OHMS, @ 1/2W, 5%, AND CAPACITOR VALUES IN MICROFARADS, @ 200V, UNLESS OTHERWISE INDICATED.
2. FACTORY ADJUST WITH OPTIMUM VALUE SHOWN.
3. ALL TUBES 7895 NUVISTORS.
4. HIGHEST REFERENCE DESIGNATORS USED:

   C9 L R49 TP17L V10

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SPECTRAL DYNAMICS CORPORATION OF SAN DIEGO

SCHEMATIC - WIDE BAND PHASE SHIFT ASSEMBLY 10025 (UPPER)	DRAWN R.G.	10242	A
	APPROVED		
	DATE 30 JULY 1965	SHEET 1 OF 1	

Figure 16d. Schematic - Wideband Phase Shifter (Upper)

with a statement of the apparent difficulty. Return of items to factory is governed by paragraphs Warranty and Shipping in the Preface of this manual.

4-4. TROUBLE SHOOTING.

If a malfunction of the analyzer occurs, refer to the Trouble Shooting Guide in this section. This guide lists probable causes and remedies for improper operation. Make certain that some external situation is not influencing the operation of the unit and that the unit is being operated properly. Look for simple causes. The SD101A is ruggedly constructed with conservative ratings on components. The SD101A should require a minimum of adjustment and repair and provide long trouble-free service.

4-5. MAINTENANCE ADJUSTMENTS.

The following are maintenance checks and adjustments that should be performed periodically as deemed necessary by the users routine calibration cycle. An initial recheck and adjustment of the instrument should be performed after approximately the first 200 hours of operation.

4-6. FREQUENCY RESPONSE. (Test Setup #1, Figure 17)

1. Place the instrument in operation in the normal manner.

2. Holding the input level constant, slowly scan the frequency range noting analyzer meter and filtered signal output level deviations. The frequency response

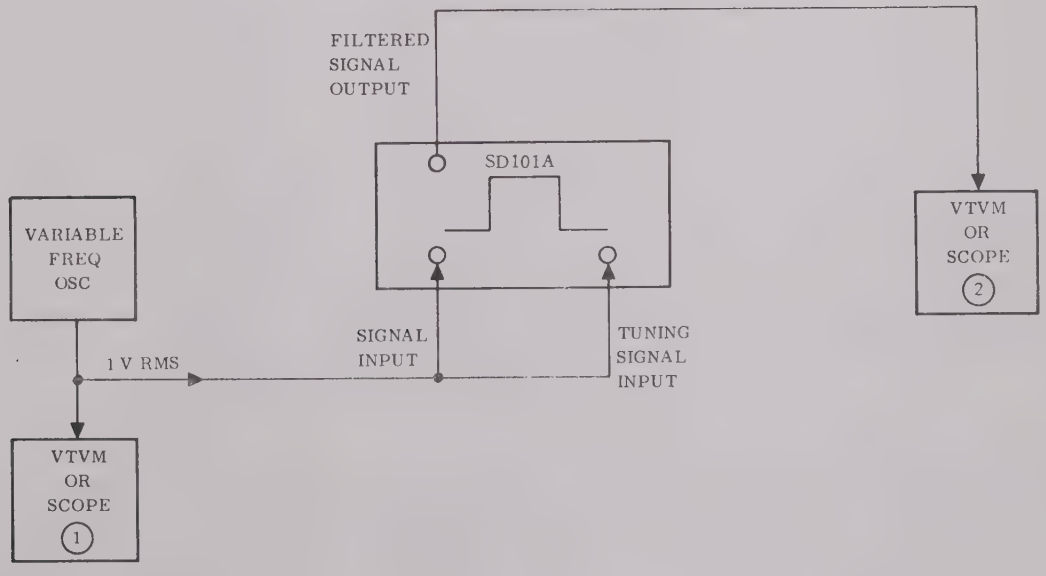


Figure 17. Test Setup #1

4-6. FREQUENCY RESPONSE (Cont'd)

as indicated by the meter, should be within ±2% of full scale from a frequency equal to ½ the filter bandwidth to 25 KC. The filtered signal output response should be ±0.25 DB from a frequency equal to ½ the filter bandwidth to 10 KC and falls off gradually above 10 KC until it is down approximately 1.0 DB at 25 KC. Excessive deviations from this characteristic indicates the wideband phase shifter is in need of factory adjustment or the carrier converter is in need of alignment (See paragraph 4-8).

4-7. SIGNAL MODULATOR BALANCE

To balance the signal modulator, use the same test setup as in 4-6. Disconnect the signal input and short-circuit the signal input terminals. Set the MULTIPLIER on .01 and adjust the tuning frequency to below ½ the bandwidth of the filter and for maximum meter deflection. Adjust the signal modulator balance control (#2, Figure 14) for null. This completes the procedure. There will be a slight fluctuation of the balance but the level of this signal is so low that it should not influence the data at frequencies higher than ½ the filter bandwidth.

4-8. CARRIER CONVERTER SIDEBAND OUTPUT ALIGNMENT

Carrier Converter alignment is required when either of the Wide Band Phase Shift circuit card assemblies (A4 or A5) are repaired or replaced (except for replacement of tubes), V14 is replaced, and in connection with periodic maintenance adjustments.

The following is designed to achieve optimum internal adjustment for lower sideband rejection, and involves the following internal controls:

A12R1 & A12R13 - Carrier Modulator Balance Controls

A12R7 - Carrier Amplitude Balance Control

R73 - Oscillator Phase Control

C90 - 100 KC Voltage Level Adjust

a. Apply 1 volt rms, 2 KC, signal to the front panel TUNING INPUT terminals and adjust the adjacent level control for 1.65 volts p-p, ±0.05 volts, at TB18-1.

   Observe the front panel TUNING AMPLITUDE meter and, if necessary, adjust the value of R252 (TB17-5 to TB18-4) for center-scale meter indication.

b. With the front panel FREQ ADJ control, set the 100 KC Oscillator for 100 KC, ±1 CPS.

   The level of the 100 KC Oscillator, measured at TB19-1, should be 25 volts p-p, ±3 volts p-p, and is adjustable by C90. If a minimum of 25 volts p-p cannot be obtained at TB19-1, add additional capacitance in parallel with C90.

4-8. CARRIER CONVERTER SIDEBAND OUTPUT ALIGNMENT (Cont'd)

c. Connect a Model H-P 310A Wave Analyzer (or equivalent) to the SD101A MKIII rear connector J11 (CARRIER SIG OUT). With the wave analyzer set for 102 KC in the 0 DB range, adjust its input level switch and variable control for a 0 DB indication on the wave analyzer.

d. With the H-P 310A set for 100 KC, adjust A12R1 and A12R13 for a minimum indication on the wave analyzer (greater than -50 DB).

e. With the H-P 310A set for 98 KC, adjust R73 and A12R7 for a minimum indication on the wave analyzer (greater than -50 DB).

f. Repeat steps d. and e. above until no further improvement is noted.

g. Remove the H-P 310A from J11. Connect a scope (with an input impedance ≧10MΩ) to J11 and observe the peak-to-peak amplitude of the carrier signal. If necessary, adjust the value of R283 (TB16-1 to TB16-3) for 65 Vp-p, ±5 volts.

Note: Some units may not actually contain resistor R283 between TB16-1 and TB16-3. Refer to schematic for recommended optimum value.

NOTE

In the absence of a wave analyzer for steps c., d., e. and f. above, the following procedure may be used. However, this method may not necessarily produce optimum performance.

(1) With an oscilloscope at rear connector J11 and without a tuning signal input, adjust A12R1 & A12R13 for minimum indication on the scope. Increase the vertical sensitivity of the scope and repeat adjustment of A12R1 and A12R13 for minimum 100 KC indication.

(2) Apply 1 volt rms, 2 KC, signal to the front panel TUNING INPUT terminals and with the adjacent level control, adjust for 1.65 volts p-p, ±0.05 volts, at TB18-1.

(3) With the scope at rear connector J11, increase the scope vertical sensitivity for a presentation of only the upper portion of the carrier. Adjust A12R6 and the 90° PHASE ADJUST, R73, for minimum ripple on the upper portion of the carrier.

(4) Repeatedly and alternately adjust A12R1 & A12R13 and then A12R6 & R73 for absolute minimum indication and until no further improvement is possible.

4-9. GAIN CONTROL

During routine maintenance, the gain of the input amplifier should be checked with the front panel GAIN control turned fully counter-clockwise to the CALIBRATED position.

After a thorough warmup, set the RANGE switch to 1.0 volt and apply an accurate 1.0 volt RMS 100 CPS signal to the signal input terminals. Adjust internal control R19 (on top of chassis between V2 and V3) for a reading of 10 volts RMS at test point 1 (#1, figure 14).

The gain of the input amplifier is now properly set at X 100.

4-10. CALIBRATION OF INTERNAL CAL REFERENCE

To calibrate the instrument's internal reference against a standard voltmeter, the following procedure is used: (NOTE: Minimum of 45 minutes warmup time)

1. Adjust input amplifier for a gain of 100 (Paragraph 4-9). GAIN control should be in CALIBRATED position.

2. Turn RANGE and MULTIPLIER to CAL, and FILTER switch to Filter 1 (filter bandwidth of 50 CPS or less).

3. Peak FREQ adjustment control carefully for a peak indication on the panel meter, adjusting Filter 1 CAL potentiometer as necessary to keep meter on scale.

4. Turn RANGE switch to 1.0 volt and MULTIPLIER to 1.0.

5. Apply an accurate 1.0 volt RMS 100 CPS signal to the signal input and tuning signal input simultaneously. Adjust Tuning Input control for centerline meter reading.

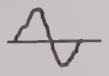
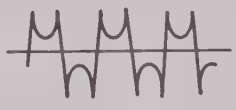
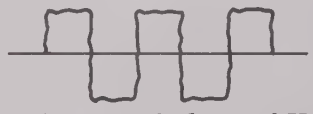
6. Note the front panel meter reading. Adjust the Filter 1 CAL potentiometer for a reading of 1.0 volt.

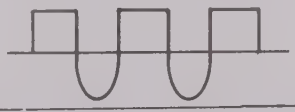
7. Return the RANGE and MULTIPLIER controls to CAL. Note the meter reading. Adjust the potentiometer marked R7 CAL ADJ located on the top left side of the chassis for a reading of 7.

Carefully lock the R7 CAL potentiometer. Recheck the 1.0 volt and CAL meter readings. Repeatability should be within ± 1% of full scale.

The internal reference is now calibrated. Normal operation may now be resumed.

4-11. TROUBLE SHOOTING GUIDE.

SYMPTOM	PROBABLE CAUSE AND REMEDY
1. No Power	Blown fuse. Replace with 2 AMP, 3AG slo-blow. If this fails, remove bottom cover and check for possible short circuit in B+ lead. B+ leads are all the red leads, with exception of leads from the transformers.
2. Distortion of Filtered Signal Output --  (Operational Trouble)	(a) Tuning signal level too low or high. Readjust to center line on tuning amplitude meter. (b) Distortion or noise in tuning signal - Clean up tuning signal waveform. (c) Filter bandwidth too wide for frequency of operation. (d) Input signal level to analyzer too high, overloading input amplifier - Change RANGE switch to higher position.
3. Distortion of Filtered Signal Output - (Equipment malfunction or misalignment) 3a. Unable to calibrate unit having insufficient gain 3b. Tuning Meter comes barely into red band when unit is on CAL	(a) Output waveform  tube failure in wideband phase shifter (#3, figure 12) - Check for sine wave along circuit boards (Test points shown in figure 15.) (b) Output waveform  Trouble same as (a) above or failure of V13 or V15 - Check for sine wave along circuit boards if sine wave present from all stages replace V13 or V15.
4. Excessive noise in filtered signal output	(a) Range Switch in wrong position - Not utilizing full dynamic range of instrument (b) Noise on power line (c) V17 or V18 is noisy - Replace

SYMPTOM	PROBABLE CAUSE AND REMEDY
	(d) Demodulator unbalanced or defective diode (CR1, CR2, CR3, and CR4) (e) Defective or noisy power supply regulator tube V4, V5, V6
5. Frequency Response falls off at low frequency	Load impedance on filtered output too low - Increase to 10K
5a. Frequency Response rises at low frequency	(a) Capacitor lead on wideband phase shifter broken, open resistor - Repair or return boards to factory for repair (b) Signal modulator unbalanced - Balance per Paragraph 4-7
5b. Frequency Response generally poor at all frequencies with dips and peaks in response	(a) Wideband phase shifter needs recalibration - or broken lead on resistor or capacitor in wideband phase shifter (b) Carrier converter needs realignment. (Ref. Paragraph 4-8.)
6. Low meter deflection on CAL and filtered signal output provides approximately 50 MV output max. and is clipped on one side 	C11 shorted, replace with 560 PFD., 200V capacitor
7. No meter deflection or recorder output, filtered signal output OK	(a) V8, V9, or V10 defective - Replace (b) C16 shorted - Replace with 560 PFD, 200V
8. No tuning Meter indication, no meter deflection, unit appears inoperative; power lights on	(a) Carrier Int. - Ext. Switch in wrong position (b) V11, V12, V14, V40, V41, V42, V16, or V19 defective
NOTE Symptoms of 6, 7, and 8 appear with unit in normal operation or in CAL.	

SYMPTOM	PROBABLE CAUSE AND REMEDY
9. No CAL signals, equipment works satisfactorily otherwise	(a) Failure of T1 (b) Broken wire in CAL circuit (c) R7 set wrong
10. Low sensitivity after unit warms up - Unable to calibrate unit - large gain drift	Filter overheating due to defective thermostat

4-12. TROUBLE SHOOTING - GENERAL.

If the above suggestions fail to correct the difficulty, then refer to the various test points cross referenced between the block diagram, schematic, figures 14 and 15, and Paragraph 4-13. Paragraph 4-13 lists the test points and illustrates the waveforms and signal voltage levels that should be present.

4-13. TEST POINTS AND ASSOCIATED WAVEFORMS AND SIGNAL VOLTAGE LEVELS.

The following test points, waveforms and voltage levels were determined under the conditions below:

A. Test Setup:

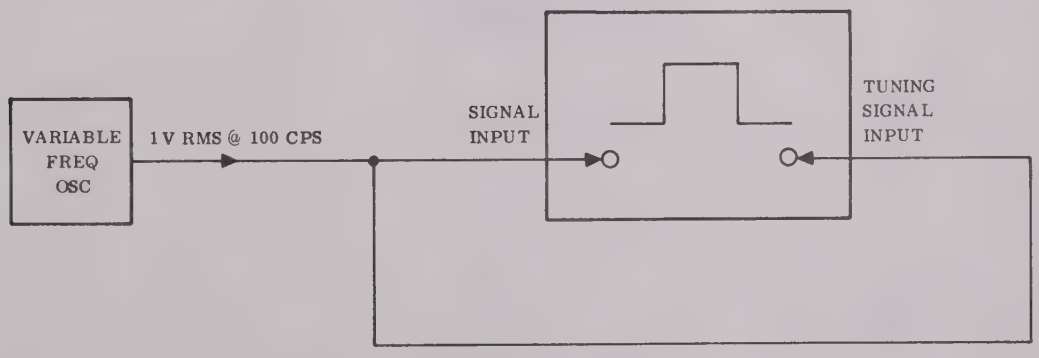
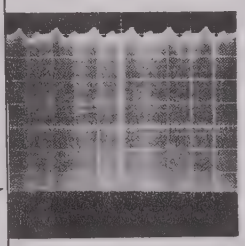
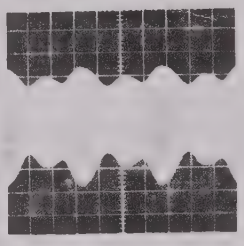
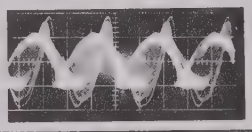
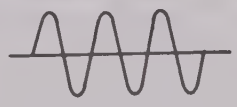


Figure 19. Test Setup #3

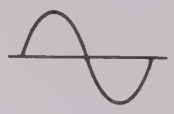
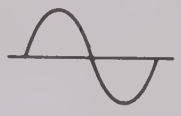
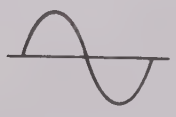
B. Voltage and waveforms were measured on a Tektronix #561 Oscilloscope using a 10-megohm probe.

C. Audio frequency amplitude measurements were obtained with a Ballantine #320 VTVM where applicable.

D. RANGE and MULTIPLIER set on 1V and 1.0, respectively, and unit aligned per Paragraph 2-1. (See figure 14 for test point locations.)

TEST POINT	WAVEFORM	VOLTAGE LEVEL
(1) Signal Frequency	Sinewave	Adjust GAIN for 28-30V p-p
(2) Signal Modulator Balance	(Refer to figure 14 for location.)	Refer to paragraph 4-7 for alignment procedure
(3) Upper sideband signal test point used for checking carrier converter alignment NOTE: Upper portion of carrier with the scope set for expanded presentation.	 Carrier Converter properly adjusted  Carrier Converter improperly adjusted	65 ±5V p-p for center scale tuning meter indication
(4) Demodulator Output Suppressed Carrier Signal		.5 V p-p approx.
(5) Tuned Amplifier Output	 100 KC sinewave	12-14V p-p approx.
(6) Meter Amplifier	100 KC slightly distorted sinewave	18 volts p-p approx.

TEST POINT	WAVEFORM	VOLTAGE LEVEL
(7) Oscillator Amplitude Control - Controls amplitude of signal appearing at Test Point (9)	Referenced for location	Early units had a fixed capacitor
(8) Oscillator Phase Control - Used for aligning carrier converter	Referenced for location	
(9) Reference Oscillator Output	100 KC sinewave	Adjust for 25 Vp-p, ±3 Vp-p @ 100 kHz.
(10) (Deleted)		
(11) (Deleted)		
(12) Carrier Modulator Drive Signal	100 KC sinewave	25 Vp-p and approx. equal to TP13.
(13) Carrier Modulator Drive Signal	100 KC sinewave	25 Vp-p (12) and (13) should be approx. 90° phase difference. The phase shift is adjusted properly when performing alignment procedure (Paragraph 4-8)
(14) Output of Upper Printed Circuit Board	Tuning Signal Frequency Sinewave	1.65 Vp-p, ±0.05 V

TEST POINT	WAVEFORM	VOLTAGE LEVEL
(15) Output of Lower Printed Circuit Board	 Tuning Signal Frequency Sinewave	1.65 Vp-p, ±0.05 V TP14 & TP15 approx. equal in amplitude and 90° out of phase.
(16) Output of Tuning Signal Amplifier	 Tuning Signal Frequency Sinewave	Approx. 3.3 Vp-p
(17) Wideband Phase Shifter Printed Circuit Cards Test Points (A) through (L) on each card. Ref. Figure 15 and schematic		
(A) Signal Input	 Tuning Signal Frequency Sinewave	Approx. 3.3 Vp-p for centerline on tuning meter
(B)-(C)-(D)-(E)-(F)-(G)-(H)-(J)-(K) Cathodes of Paraphase Amplifiers	Tuning Signal Frequency Sinewave	Gain approx. .95 per stage.

TEST POINT	WAVEFORM	VOLTAGE LEVEL
(17) (Continued) (L) Output	 Tuning Signal Frequency Sinewave	1.65 Vp-p, ±0.05 V
(18) Filter Input	 Modulated Signal Frequency	3-4V p-p
(19) (Deleted)		
(20) B+ from Power Supply		150V DC
(21) Recorder Circuit		1.3 - 1.8V DC with recorder output adj. full clockwise
(22) Filtered Signal	 Signal Frequency Sinewave	28 volts p-p with filtered signal output adj. full clockwise

SECTION V

TABLE OF REPLACEABLE PARTS

5-1. GENERAL

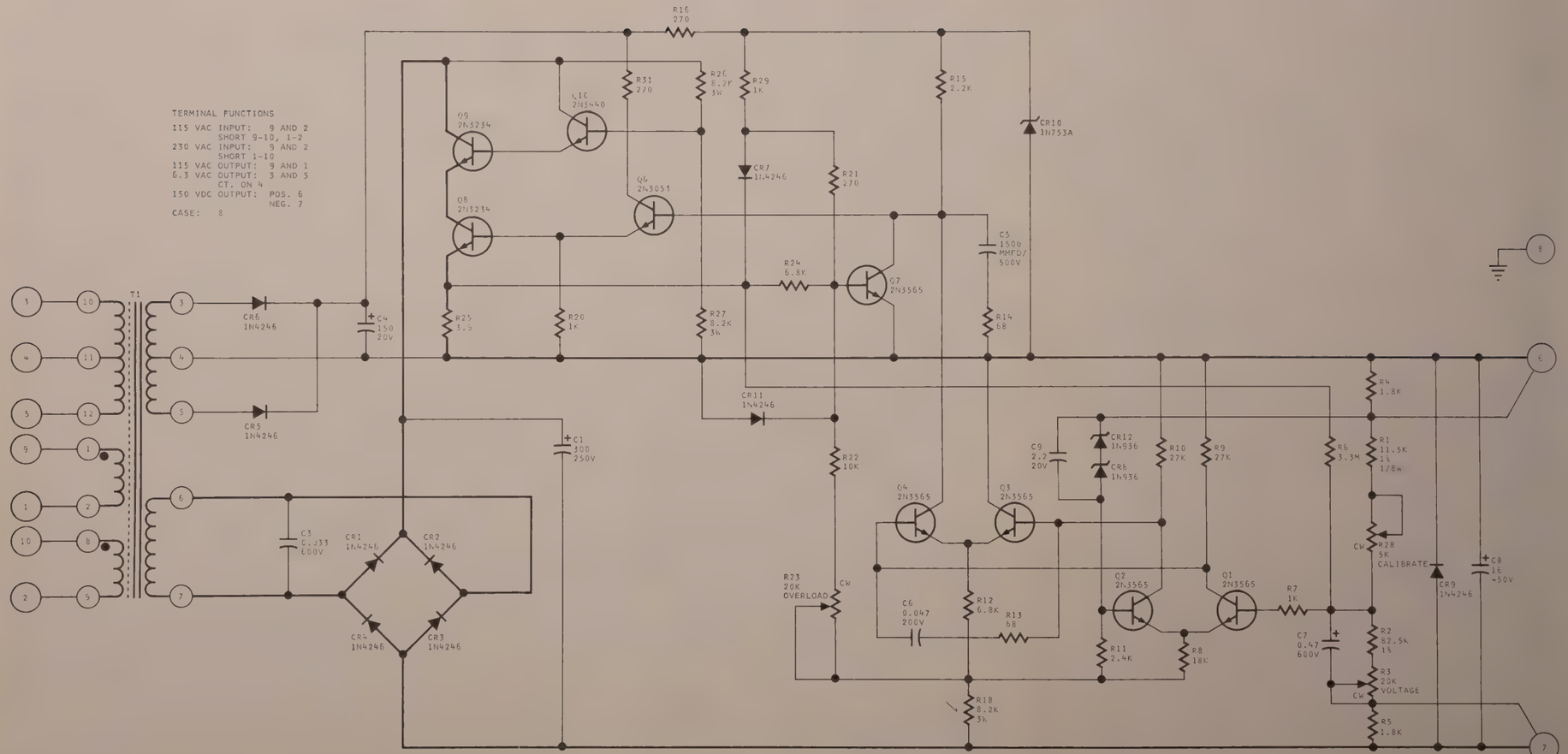
Standard electronic components have been used in this instrument wherever possible and may be ordered direct from Spectral Dynamics Corporation.

All orders for replacement parts and/or assemblies should include available part number information, reference designation, complete description of the item, as well as the Model and serial number of the instrument.

The following table contains a list of special items that must be ordered direct from Spectral Dynamics Corporation in order to ensure complete compatibility.

Table 5-1. Special Replaceable Parts

Reference Designation	Description	Part Number
A1 A2	Filter, Bandpass	Order by Model No.
A3 A3	Oven Assembly (less crystal) Crystal, 100 kHz	20013-112 JK H17T
A4 A5	Wide Band Phase Shift Assy.(A4 Upper) Wide Band Phase Shift Assy.(A5 Lower)	10025-1 10026-1
A6	Filter, 30 kHz Low-Pass	20013-012
A7	Power Supply (115VAC only) Power Supply (115/230VAC)(solid-state)	10050-1 20013-130
A8	Demodulator	20013-013
CR2A/CR2B	Diode, Matched Pair (CD6112)	20013-135
A12CR1-CR4 A12CR5-CR8	Diode, Matched Quad (1N914) Diode, Matched Quad (1N914)	20013-102
M1 M2	Meter, Model 561 Meter, Model 361	10003 10002
T2 T10	Transformer Transformer	20013-059 20013-117
A12T1 A12T2 A12T3 A12T4	Transformer	20013-067



REVISIONS

NO.	DESCRIPTION	DATE

NOTES:

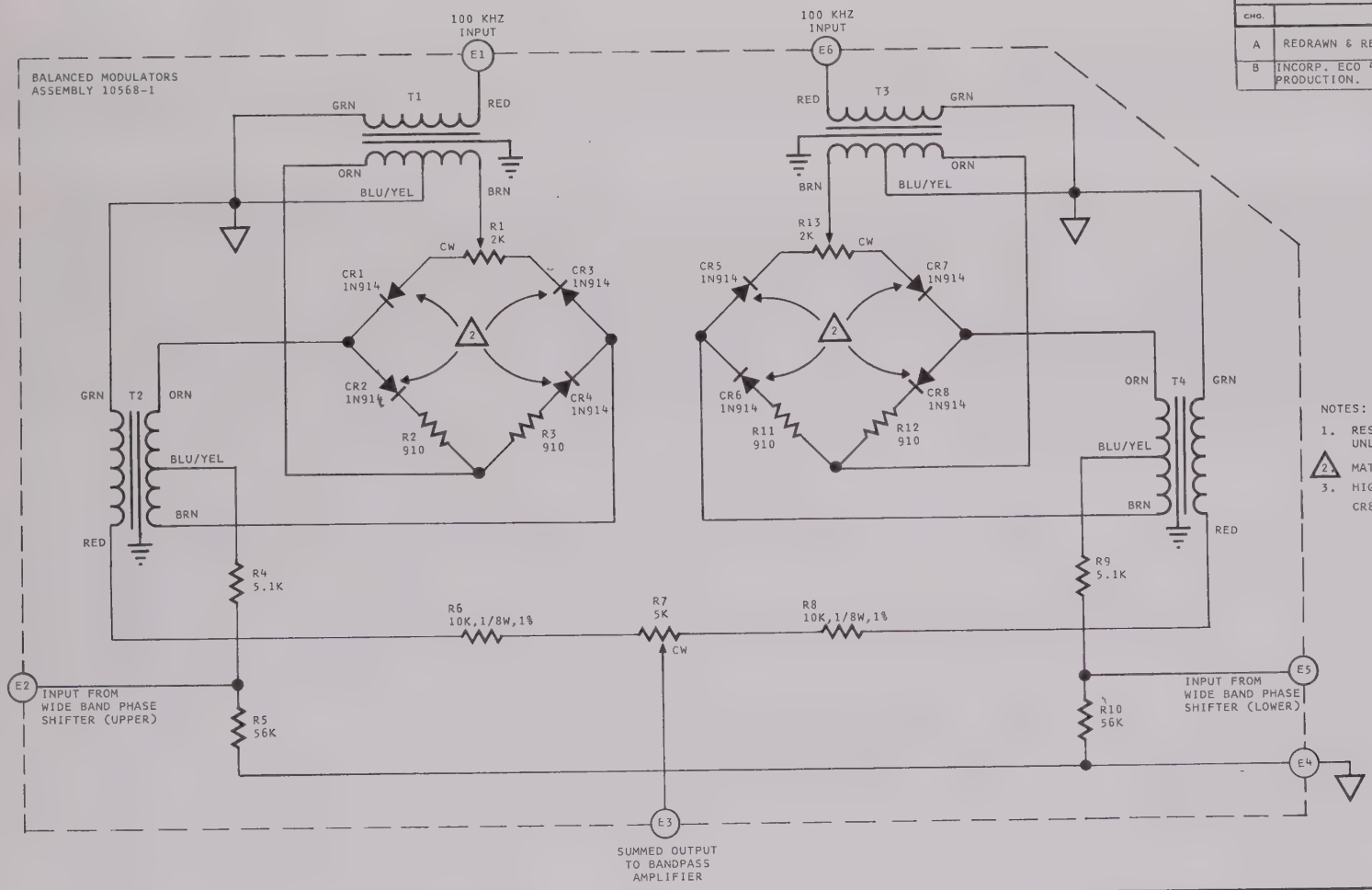
1. RESISTOR VALUES IN OHMS @ ¼W, 5% AND CAPACITOR VALUES IN MICROFARADS, UNLESS OTHERWISE INDICATED.
2. SPECIFICATIONS:
   - INPUT - 115/230 volts ac, 50 TO 400 Hz.
   - OUTPUTS - 140 - 160 volts dc @ 0.125A. 115 volts ac @ 50VA max. unreg. 6.3 volts ac @ 9A max. unreg.
   - REGULATION - 0.05% for line changes of 10%. 0.05% for NL to FL.
   - RIPPLE - 1 millivolt rms maximum.
3. HIGHEST REFERENCE DESIGNATORS USED:

   C9 CR12 Q10 R31 T1

SPECTRAL DYNAMICS CORPORATION OF SAN DIEGO

SCHEMATIC - POWER SUPPLY	DRAWN L.W.	20013-130
	APPROVED	
	DATE 7 SEP 1966	SHEET 2 OF 2

REVISIONS		
CHG.	DESCRIPTION	DATE
A	REDRAWN & RELEASED. R.P.	4/67
B	INCORP. ECO 416 EFFECTIVE ALL FUTURE PRODUCTION. WICKLUND	10/67



NOTES:

1. RESISTOR VALUES IN OHMS @1/4W, 5%, UNLESS OTHERWISE INDICATED.
2. MATCHED QUAD PER SDC SPEC. 20013-102.
3. HIGHEST REFERENCE DESIGNATORS USED:
   CR8 E6 R13 T4

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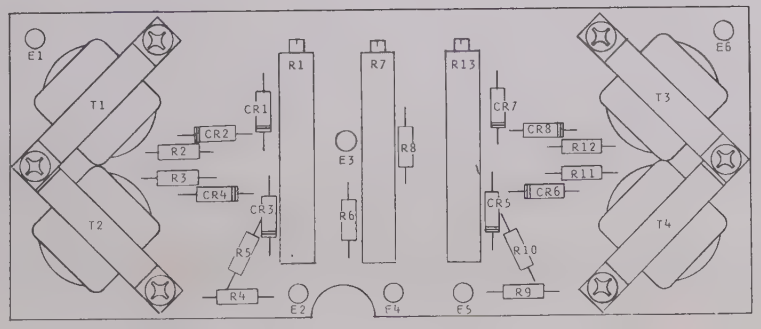


SPECTRAL DYNAMICS CORPORATION OF SAN DIEGO

BALANCED MODULATORS ASSEMBLY 10568-1

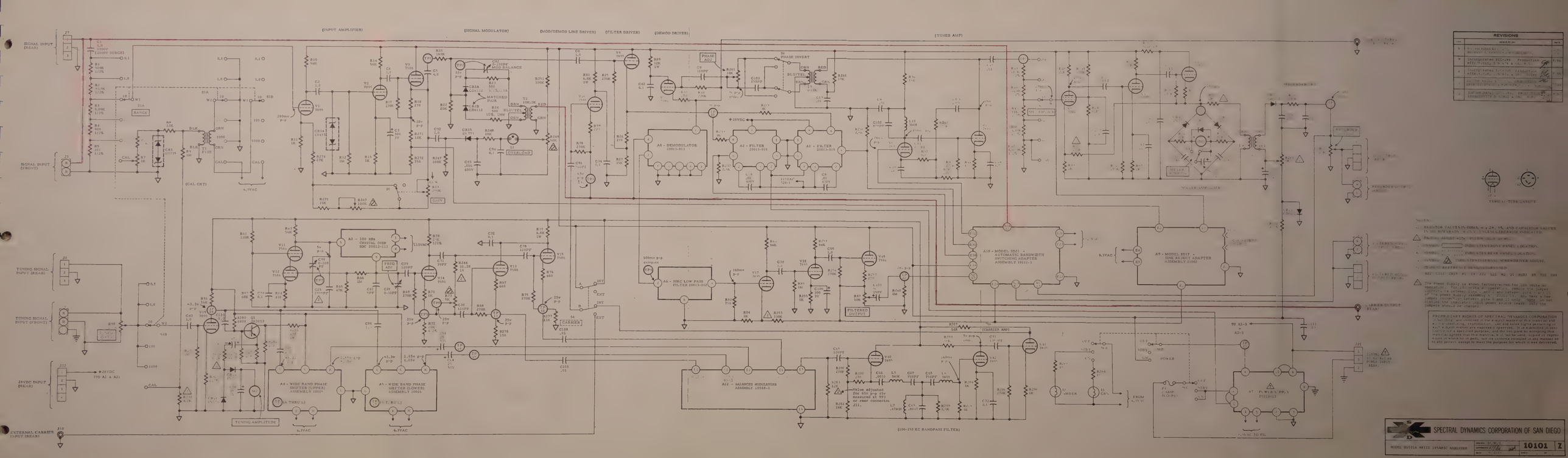
DRAWN R. PETRO

APPROVED

DATE 4-19-67

10612 B

SHEET 1 OF 1



REVISIONS		
LTR	DESCRIPTION	DATE
A	[illegible]	[illegible]
B	[illegible]	[illegible]
C	[illegible]	[illegible]
D	[illegible]	[illegible]
E	[illegible]	[illegible]

NOTES:
1. RESISTOR VALUES IN OHMS, K = 1,000, M = 1,000,000. CAPACITOR VALUES IN MICROFARADS, UNLESS OTHERWISE INDICATED.
2. FACTORY ADJUSTMENT. SYSTEM GAIN (20 dB NOM.)
3. [illegible] INDICATES FRONT PANEL LOCATION.
4. [illegible] INDICATES REAR PANEL LOCATION.
5. [illegible] INDICATES INTERNAL SCREWDRIVER ADJUST.
6. [illegible] REFERENCE DESIGNATIONS USED:
A22 1111 C819 F1 T1 222 522 R2 Q1 8283 88 702 V49
7. For Power Supply as shown factory-wired for 220 volts AC operation. For 105, 115, & 125 volts AC operation, change jumper connects as follows: Jump 1 and 2, and Jumper 3 and 4 of T1 power supply transformer. Also make a new jumper connection between pins 1 and 2 only. Note: Do not change fuse F1 on power supply board. Fuse shall be [illegible] as shown.

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SPECTRAL DYNAMICS CORPORATION OF SAN DIEGO
MODEL SD301A MKIII DYNAMIC ANALYZER
SIZE D | 10101 | Z

(PART TWO)

SERIAL NO. _____

INSTRUCTION MANUAL

SD21 AUTOMATIC BANDWIDTH SWITCHING ADAPTER

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Telephone 714–278–2501

Revised
April 1966

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SECTION I

GENERAL INFORMATION

1-1. INTRODUCTION.

The Model SD21 Automatic Bandwidth Switching Adapter was designed to be installed in the Model SD101, SD101 Mark II, or Model SD101A Dynamic Analyzer and performs the following functions:

1. Automatic Bandwidth Switching

   The Dynamic Analyzer has accommodations for two plug-in type crystal filters manually-selectable by use of a front panel switch. The Model SD21, when installed in the Dynamic Analyzer, allows the operator to automatically switch filters at a preset frequency while the system sweeps the spectrum. The manual mode of operation is retained.

2. Bandwidth Division

   When the Dynamic Analyzer is used in a Power Spectral Density (PSD) Analysis System, the system mustbe calibrated for the particular plug-in filter being used. The Model SD21 maintains the calibration as the filters are automatically selected.

3. Time Averaging

   When the Dynamic Analyzer is used in a PSD Analysis System, capacitors must be employed on the DC output to provide a suitable averaging time for the energy being passed through the filter. The SD21 has accommodations for two plug-in type capacitors to provide predetermined time averaging for the two filters.

4. Compressor Optimizing

   In Sine and Sine-Random Vibration Testing, the sine-servo circuit must be optimized to the particular Tracking Filter Bandwidth being employed. This optimization is accomplished by adding capacitors in parallel with the capacitors in the sine-servo circuit of the vibration system.

   Two pairs of banana-type jacks are provided in the SD21 to accommodate two plug-in type optimizing capacitors; one for each filter in the Dynamic Analyzer. Once the proper value for each filter has been selected, the

SD21 automatically switches the capacitors to maintain servo stability over the entire operating frequency range.

1-2. GENERAL DESCRIPTION.

The SD21 Automatic Bandwidth Switching Adapter is shown in Figure 1. Following is a discussion of the controls, connectors, and components which are referenced in Figure 1.

1. J3 FILTER 1 AVERAGING:

   J3 accommodates the plug-in damping capacitors for FILTER 1 and is used in PSD Analysis applications.

2. J2 FILTER 2 AVERAGING:

   J2 serves the same function as J3 except that it is for FILTER 2.

3. K3 RELAY:

   K3 switches between filters in the Dynamic Analyzer.

4. K1 RELAY:

   K1 grounds the output of the broad bandwidth filter when the narrow filter is selected (manually or automatically). This eliminates crosstalk that occurs within K3 Relay.

5. K2 RELAY:

   K2 selects the appropriate averaging capacitors for PSD Analysis applications.

6. K5 RELAY:

   K5 selects the appropriate optimizing capacitor for Sine or Sine-Random Vibration Testing.

7. V1, V2 AND V3:

   V1 is the input amplifier. The voltage comparator (V2 and V3) operates a sensitive relay (K4) located inside the SD21 chassis.

8. CROSSOVER ADJ:

   The trimpot located on the printed circuit board is the filter crossover adjustment. The filter crossover point can be adjusted anywhere within the range of 0.1 to 10 volts DC. The signal actuating the SD21 is a DC signal proportional to frequency provided by external equipment such as a servo cycling oscillator, frequency to DC converter, etc.

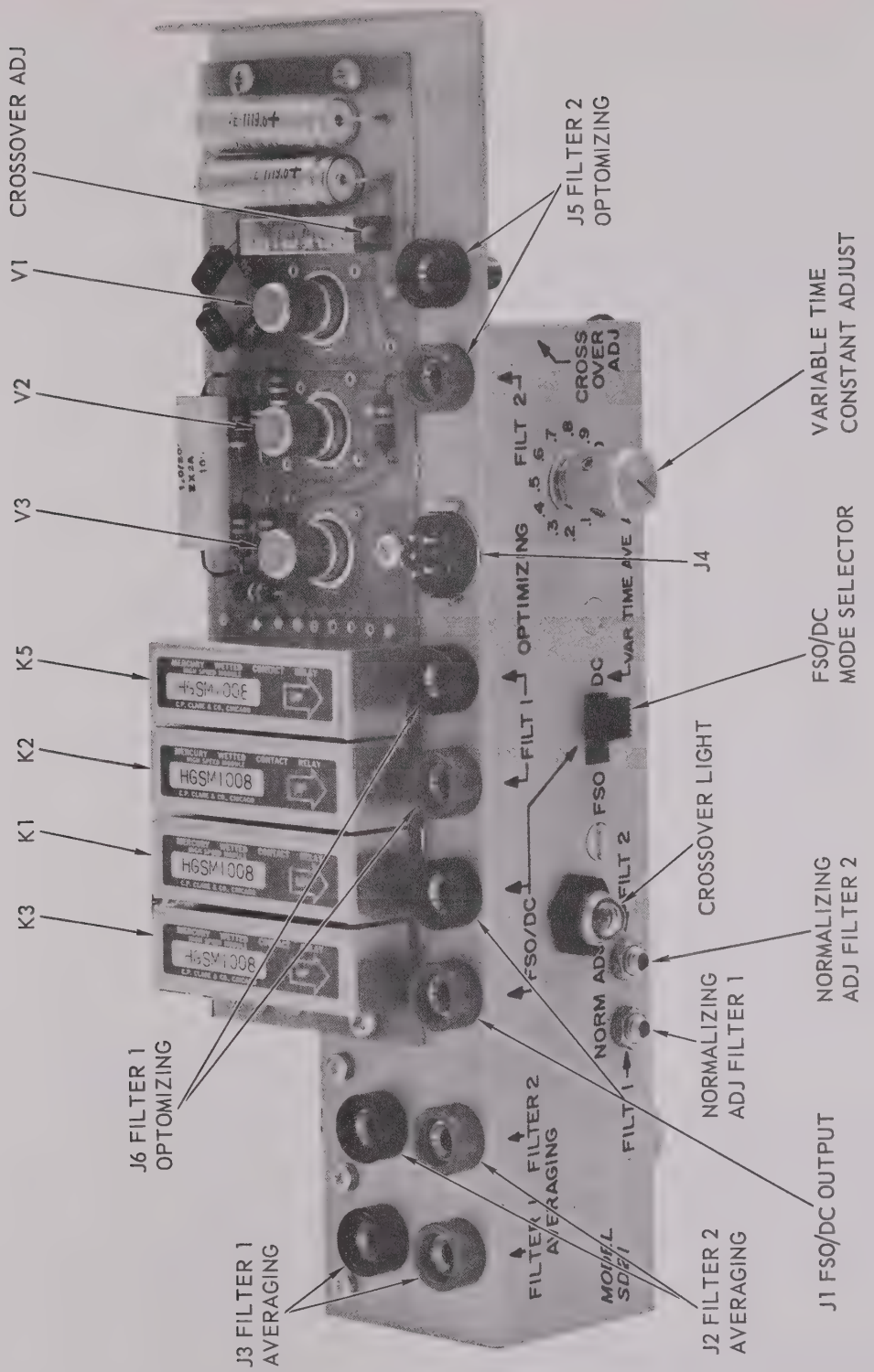


Figure 1. SD21 Automatic Bandwidth Switching Adapter

9. J5, FILTER 2 OPTIMIZING:

The two banana-type jacks accommodate the compressor optimizing capacitor for the broad filter.

10. J4 CONNECTOR:

J4 is the SD21 input connector for the DC signal which operates the relays and the servo compressor DC signal for compressor optimizing.

11. VARIABLE TIME AVE ADJ:

The potentiometer, calibrated from 0 to 1, is used in PSD applications to provide a variable control of RC time averaging.

12. FSO/DC MODE SELECTOR:

The slide switch labeled FSO/DC is used to select the mode of operation desired. PSD analysis can be performed using the analyzer's DC or AC (FSO) output.

13. J6 FILTER 1 OPTIMIZING:

The two banana-type jacks accommodate the compressor optimizing capacitor for the narrow filter.

14. J1 FSO/DC OUTPUT:

The FSO/DC output (banana-type jacks) is the analyzer FSO or DC output as selected by the FSO/DC slide switch.

15. NORMALIZE ADJ FILTER 1 AND 2:

These two trimpots are used to normalize the outputs of the two filters. FILTER 2 NORMALIZE ADJ is also used in PSD analysis to provide Automatic Bandwidth Division. These potentiometers are located on the front panel of the Model SD101A, serial numbers 300 and on.

16. FILTER SELECTOR SWITCH:

The filter selector switch, located within the chassis beneath J2 and J3, is used to manually switch between the two filters, bypass the filter or place the analyzer in the Automatic Bandwidth Switching Mode of operation.

1-3. INSTALLATION RECOMMENDATIONS.

When the Model SD21 is installed in a Dynamic Analyzer/Tracking Filter, the calibration and operating controls are located on the top side for convenience to the operator. Use of chassis slides is recommended to facilitate changing plug-in filters, making calibration adjustments, etc. The SD101A chassis is pre-drilled to accept slides, which are available from the factory for a very nominal charge. Connectors for the plug-in damping capacitors and external leads are available on the rear of the SD21 chassis.

1-4. SPECIFICATIONS.

Circuitry:	Nuvistorized
Input Impedance:	10 megohms ± 10%
Stability:	Will maintain any given set level for a minimum of 8 hours within plus or minus 2% of full range.
Hysteresis:	Less than 2% of threshold voltage between relay pull-in and drop-out.
Power Requirements:	Supplied by SD101, SD101 Mark II, or SD101A.
Operating Range:	Crossover adjustable for any positive threshold voltage between 0.1 and 10 Volts DC.
Mounting:	Behind front panel of SD101, SD101 Mark II, or SD101A. Secured in position by filter selector switch and two mounting screws.
Operating Position:	SD101, SD101 Mark II, or SD101A must only be operated in normal upright position, due to the use of mercury-type relays in the SD21.

1-5. THEORY OF OPERATION.

The electronic circuits in the SD21 (Figure 2) consist of a single stage of amplification coupled to a two-stage voltage comparator. Amplification reduces the inherent hysteresis of the comparator circuit by the gain factor of the amplifier. A positive DC voltage at the grid of V1 will increase conduction through the tube, thereby lowering the plate voltage. Any plate voltage variation of V1 is coupled to the grid of V2 which is one stage of a Schmitt circuit or cathode-coupled binary, in a state of conduction. When the grid voltage of V2 decreases below that of V3 (in a stable "off" state), the conduction states reverse. As V3 goes into conduction, the sensitive relay, K4, energizes and operates the SD21 control circuit relays.

The crossover point, is set by the CROSSOVER ADJ potentiometer (R4) which controls the cathode bias voltage of V1. When the DC voltage at the grid of V1 is a ramp function within the operating voltage limits, and proportional to frequency, the crossover point may be set to operate at any desired frequency.

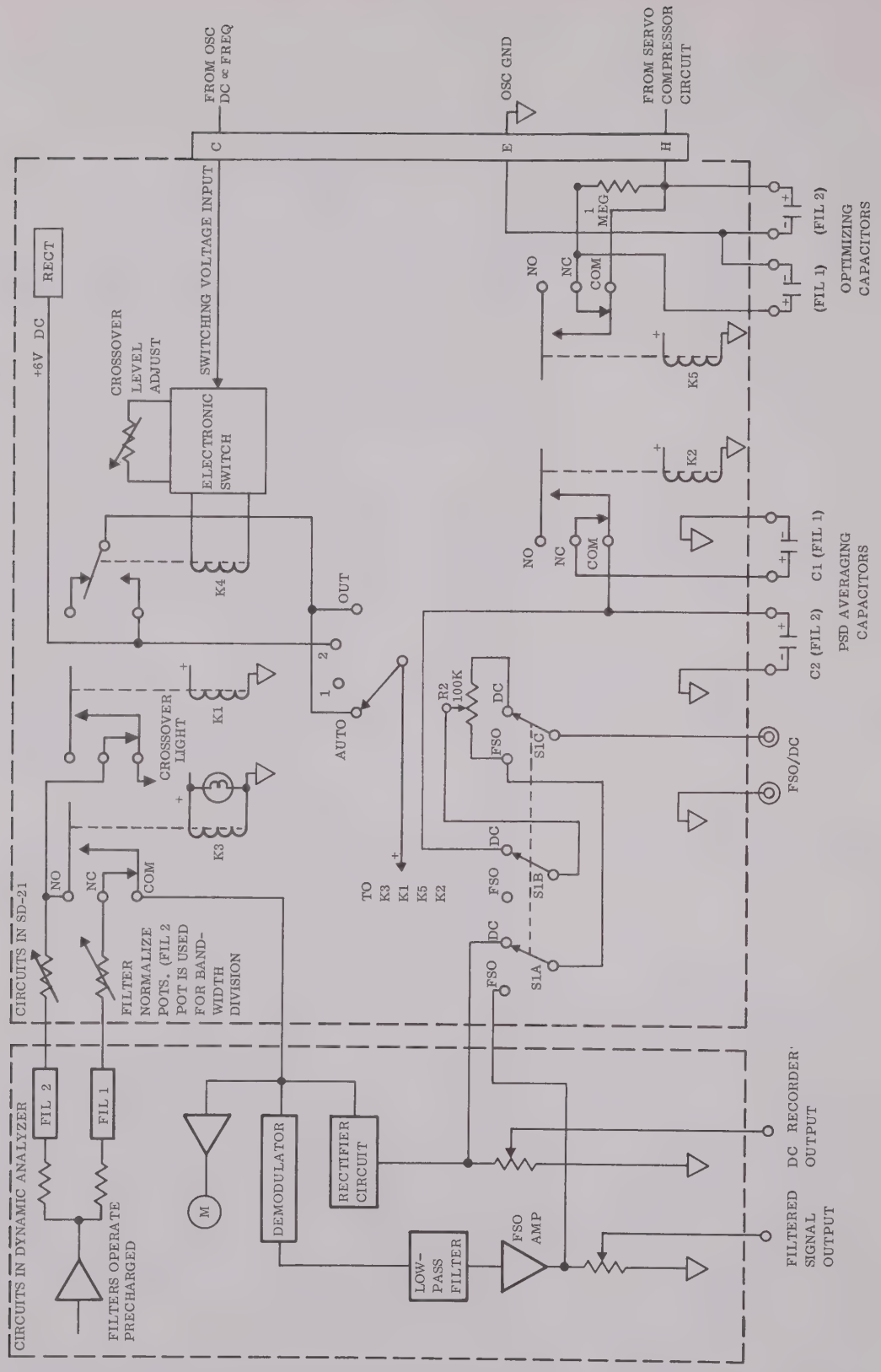


Figure 2. Simplified Block Diagram of SD21 connected to Dynamic Analyzer

SECTION II

USE OF SD21 IN SINE AND SINE-RANDOM VIBRATION TESTING

2-1. GENERAL DISCUSSION.

The Dynamic Analyzer/Tracking Filter is widely used in shaker systems to eliminate signal distortion from affecting the accuracy of the Servo Control System. In other words, it allows servo control of the fundamental input to a specimen. As observed in the typical test setup shown in Figure 3, the measured acceleration level at the Shaker Table is filtered and applied to the Servo control circuit where it is compared with a reference, or set vibration level. If a difference between the measured and referenced levels exists, an automatic correction is applied to increase or decrease the oscillator output to re-establish equilibrium in the system at the preset vibration level.

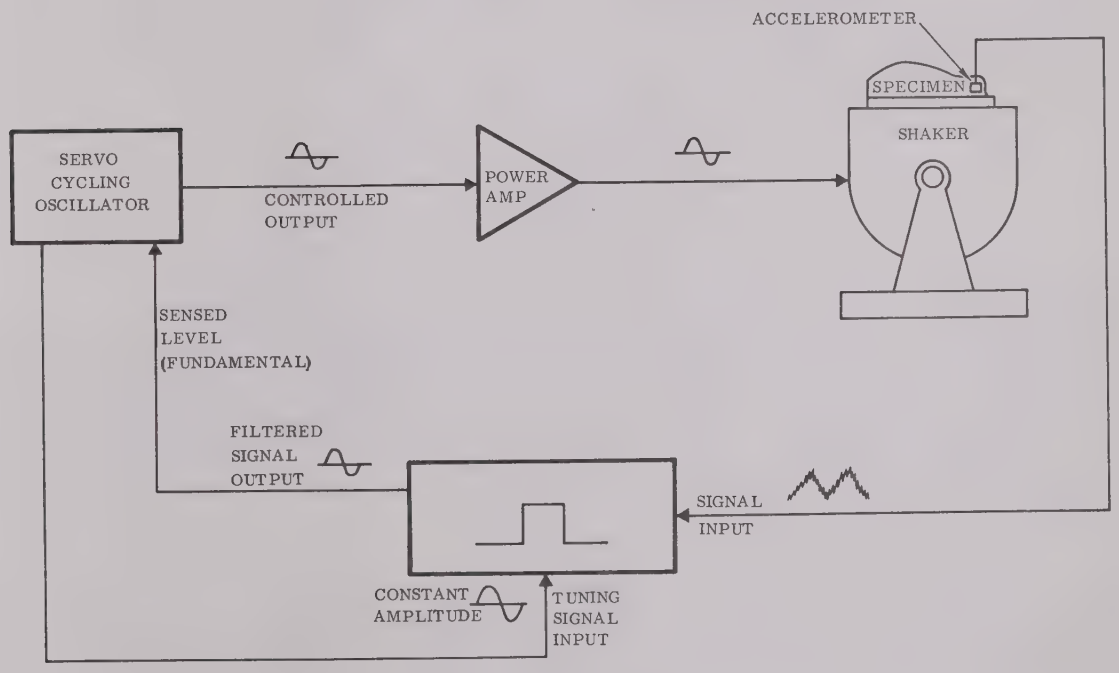


Figure 3. Typical Test Setup for Sinewave Vibration Test

Figure 4 is a simplified block diagram of a typical Sine Servo System.

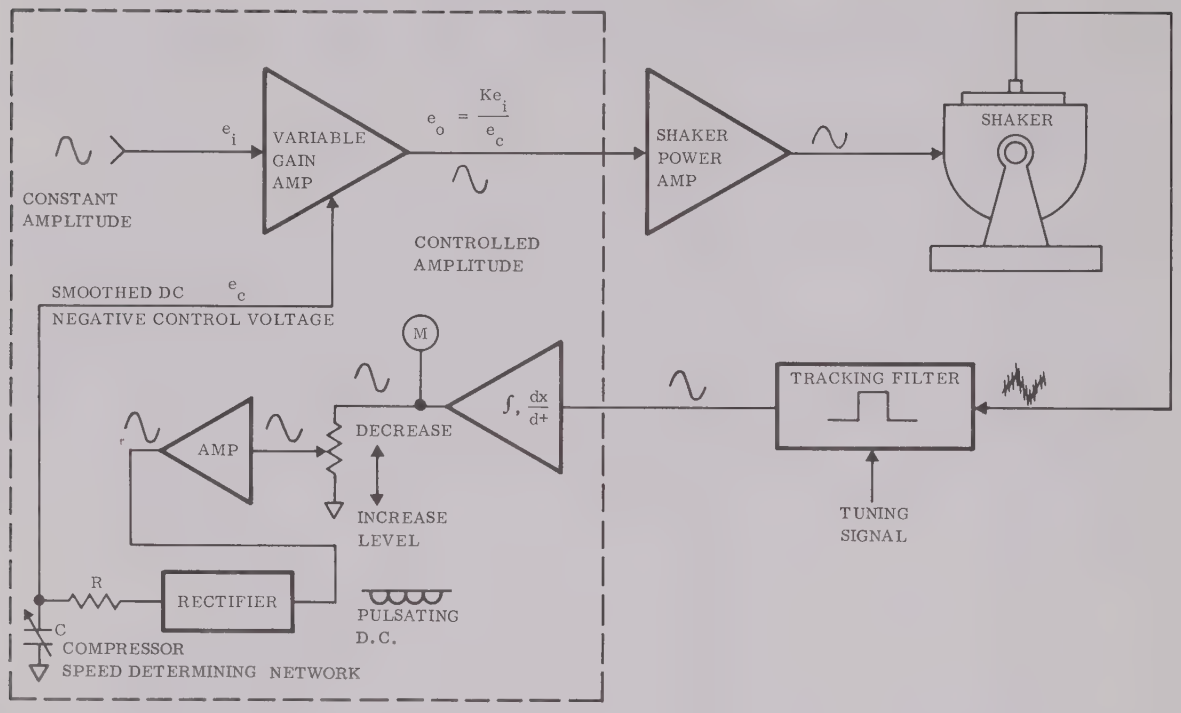


Figure 4. Simplified Block Diagram of Typical Sine Shaker Servo System

A Tracking Filter has a response delay or a time constant of approximately 1/BW in seconds, where BW = 3 DB bandwidth of filter. If the delay through the tracking filter or sensing circuit is longer than the delay of the correction device (the variable gain amplifier and RC circuit), a condition of low servo damping or instability exists. To re-establish stability, the response of the sensing circuit must be increased or the response of the correction circuit decreased.

In B & K-type Servos, this offers no particular problem since several selectable compressor speeds are available. The various speeds are provided to handle narrow bandwidth resonances in a specimen, since they also present a delay in the measuring loop and can cause a servo instability.

It is generally desirable to operate with slow compressor speeds in the low frequency range (using a narrow filter) and fast compressor speeds in the high frequency range (using a broad filter). Therefore, the SD21 is utilized to automatically switch between filters and provide optimum compressor speeds.

2-2. COMPRESSOR OPTIMIZING.

Optimizing a given servo system is simply a procedure for obtaining the optimum shaker servo recovery speed and damping. The response to a step input is the common method of showing the damping characteristics of a closed loop system. A typical test setup is shown in Figure 5. For safety reasons, the shaker is removed from the loop and in general, the results obtained with and without the shaker in the loop will be very similar. Figure 6 shows three different response functions representing underdamped, properly damped, and overdamped response.

The damping characteristics of different types of servos will vary depending on the amount of compression used in a servo. The system will have less damping and be less stable as compression is increased and conversely the system will have more damping and be more stable as compression is decreased.

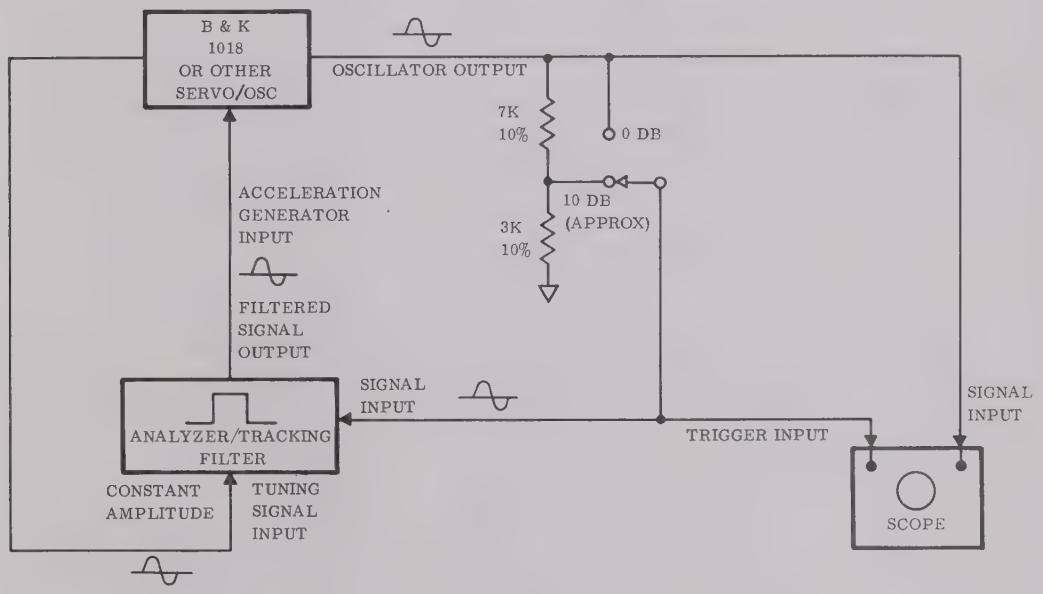


Figure 5. Compressor Response Test Setup

As shown in Figure 7, the capacitors in the B & K Compressor Circuit are removed as the relays progressively actuate. As this occurs, the speed of response of the compression amplifier is increased. The relays are actuated progressively by a shorting-type switch mounted in the frequency dial of the B & K. Figure 7 shows the compressor speed as a function of the relay that is actuated. The speeds shown only apply

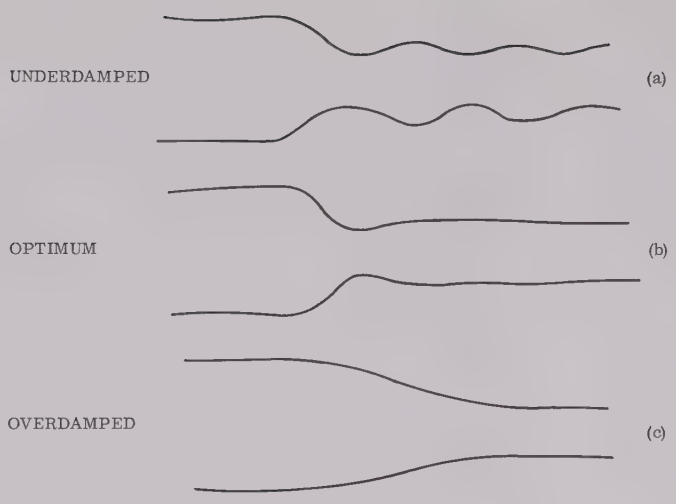


Figure 6. Typical Compressor Response Curves

when the B & K is operated in the STANDARD-AUTOMATIC mode. Other modes of operation such as Hi-Q and Med-Q modify the sequence of relay actuation and make the compressor speeds slower. Therefore, they will not affect the following optimizing procedure. The FAST mode will affect the optimized performance, since it is faster than STANDARD.

B & K COMPRESSOR SPEEDS

FREQUENCY RANGE (CPS)	B & K Compressor Speeds in DB/SEC			
	HIGH "Q"	MEDIUM "Q"	STANDARD	FAST
5 - 30	10	10	10	30
30 - 100	10	10	30	90
100 - 300	10	30	100	300
300 - 1000	30	100	300	900
1000 - 3000	100	300	1000	3000
3000 - 5000	300	1000	3000	3000

A rule of thumb concerning tracking filter bandwidth and compressor speed is:

Maximum compressor speed (DB/SEC) = 8 × Filter Bandwidth

This equation was empirically determined. However, there appears to be considerable variation in the measured compressor speed between various B & K Oscillators of the

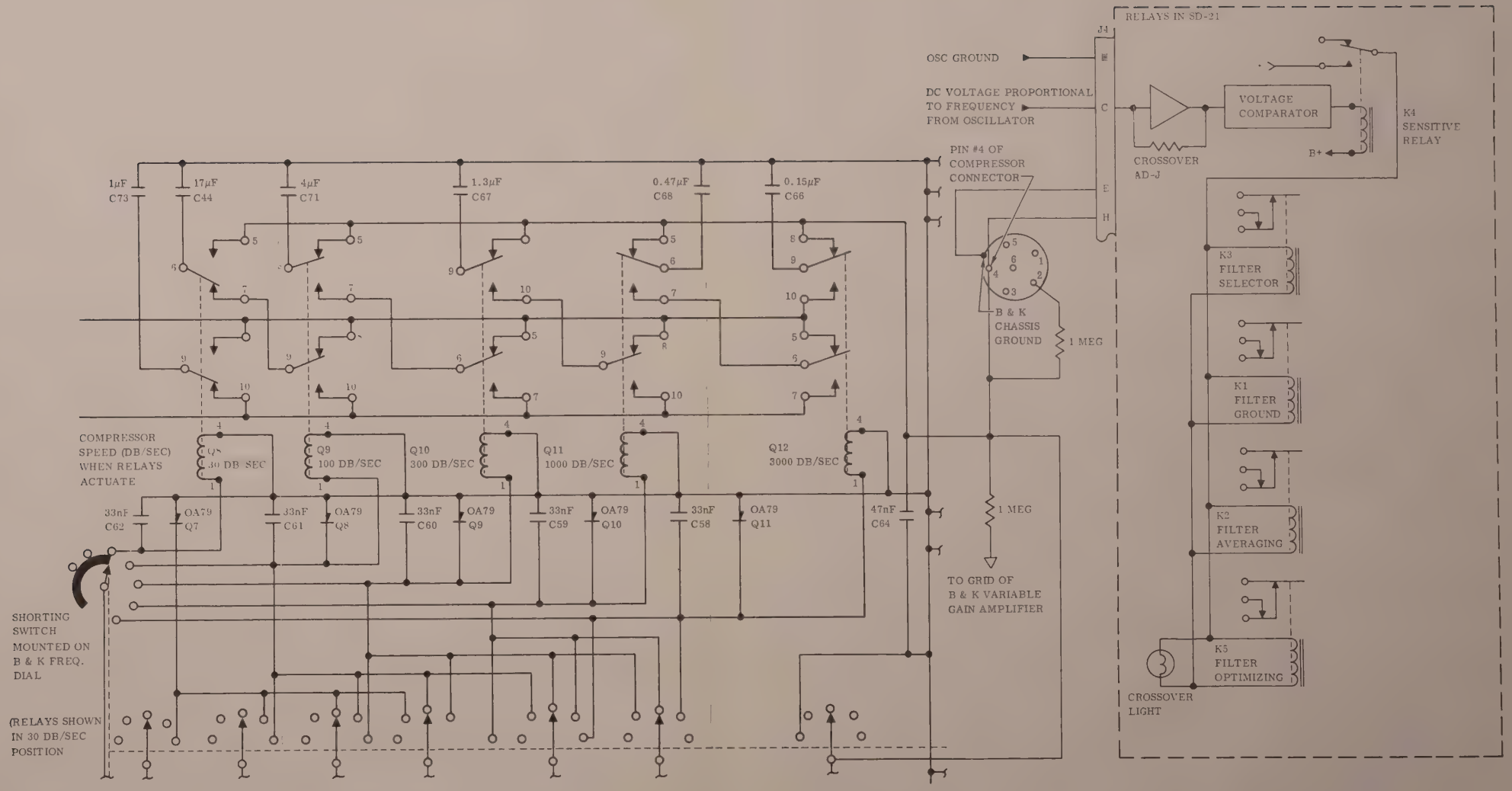


Figure 7. B & K Compressor Circuit Showing Connections to SD21

same type. This is principally due to the tolerance stackup on the R's and C's used in the compressor circuit. For this reason, the compressor must be optimized using the test setup shown in Figure 5 and observing the closed-loop response of the Servo with the tracking filter placed in the feedback loop (Figure 6).

From the above it is seen that the bandswitching should be used at a predetermined frequency to give the response desired for sine wave tests, and optimizing be performed for best system performance for sine-random tests.

The Dynamic Analyzers (SD101, SD101 Mark II, and SD101A) have provisions for two filters. The filters used depend on the particular requirements of an application. For Sine Testing, using the SD21 automatic bandwidth switching, a 10 CPS and 100 CPS filter will generally meet all requirements.

For Sine-Random Testing, the 10 CPS is commonly used. Bandwidth switching is not used but the optimized response is desired. Unless the servo and filter combination has been optimized previously for sine tests, optimizing should be performed again any time the filter bandwidth is changed.

2-3. OPTIMIZING PROCEDURE FOR B & K MODEL 1018/1038 AND SHAKER MANUFACTURERS EQUIVALENT.

It is not necessary to remove the B & K Oscillator from the relay rack or to remove its cover. Interconnections from the B & K to the Dynamic Analyzer/Tracking Filter and SD21 are made at existing connectors on the rear of the B & K Oscillator. The optimizing procedure is as follows:

1. Install an interconnecting cable between J4 on the SD21 and the B & K Oscillator as shown in Figure 8.

2. Make test setup shown in Figure 5.

3. Select the two filter bandwidths to be used.

4. Install the narrower bandwidth filter in the FILTER 1 position and after a 30-minute warmup, calibrate the analyzer using the narrow filter. Switch to the broad filter and adjust the FILTER 2 NORMALIZING potentiometer for the CAL meter reading of 7. Do not readjust the FREQ control when switched to FILTER 2.

5. Using the chart in Figure 9, and the equation, maximum compressor speed = 8 × BW, determine the desired crossover point. The crossover frequency should not be lower than one-half the bandwidth of the broad filter. The chart (Figure 9) shows the compressor speeds of the B & K operated in the STANDARD, AUTOMATIC mode.

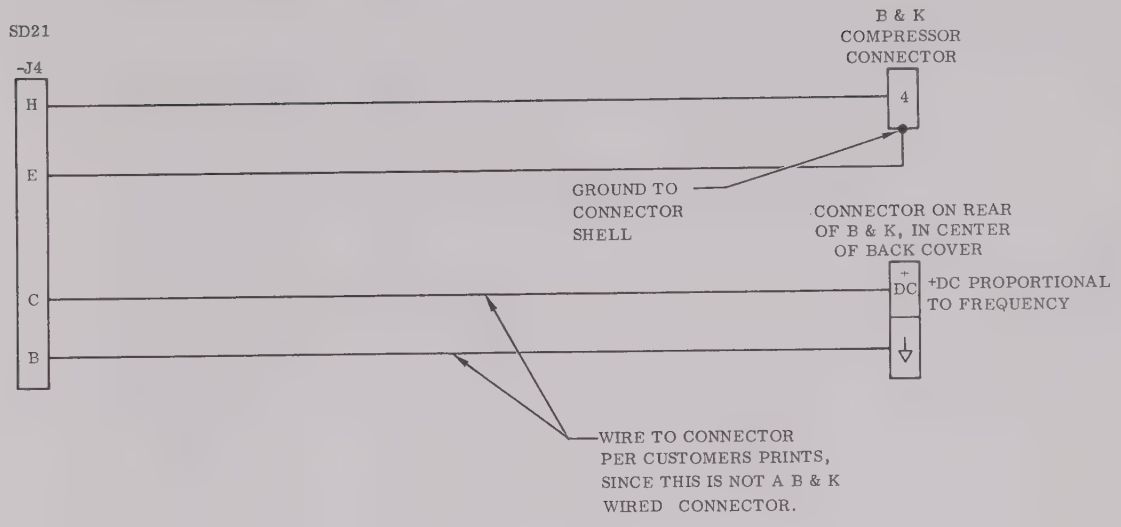


Figure 8. Cable Connection Between SD21 and B & K Oscillator

Example: Selection of crossover point:

(a) Using a 10 CPS and 100 CPS filter: A 10 CPS filter provides a response rate of $8 \times 10 = 80$ DB/SEC and a 100 CPS filter provides a response rate of $8 \times 100 = 800$ DB/SEC. Referring to chart (Figure 9), good response is obtained up to 300 CPS if the 100 DB/SEC range is optimized. Therefore, the crossover point can be set at 300 CPS.

(b) Using a 5 CPS and 100 CPS filter: A 5 CPS filter provides a maximum response rate of 40 DB/SEC and a 100 CPS filter provides a maximum response rate of 800 DB/SEC. Set the crossover point at 100 CPS. It is probable that optimizing capacitance will not be required since the response of the 5 CPS filter should be faster than the servo compressor.

(c) Using a 20 CPS and 100 CPS filter: A 20 CPS filter provides a response rate of 160 DB/SEC and a 100 CPS filter provides a response rate of 800 DB/SEC. Set crossover point at 300 CPS.

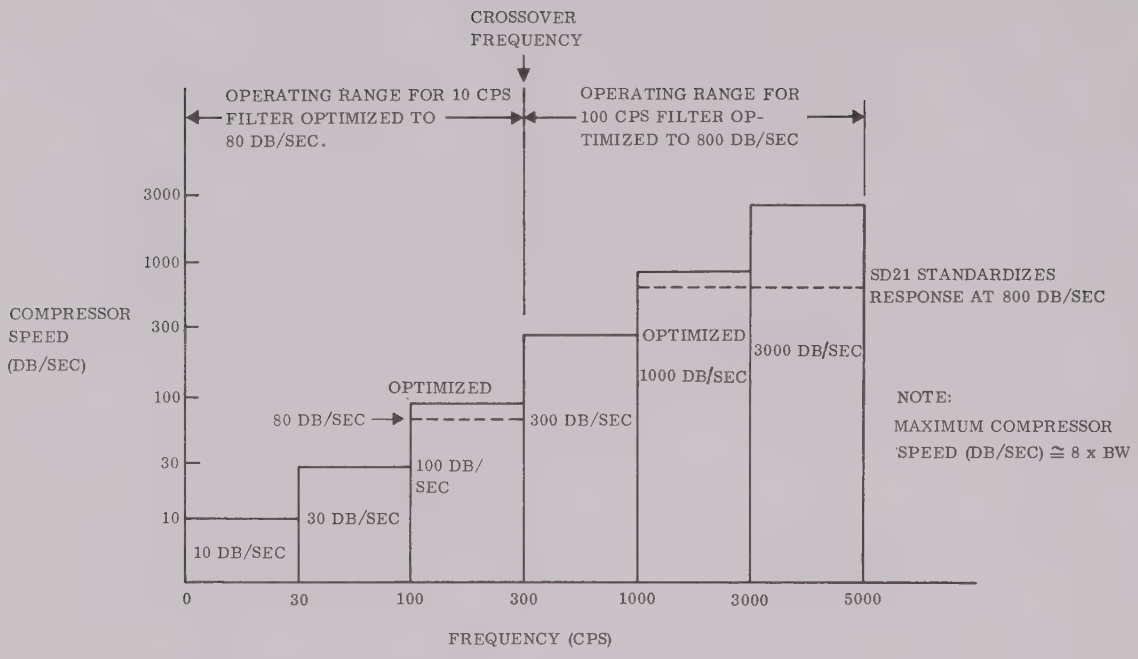


Figure 9. Compressor Speed Ranges for B & K 1018/1038 Servos

6. Manually select the narrow filter in the Dynamic Analyzer and set the B & K to a frequency slightly below the desired crossover point. then set the Dynamic Analyzer for unity gain on the 0.1-volt range. (B & K Compressor turned off.)

7. Set the step switch (Ref. Figure 5) to 0 DB position.

8. Set the B & K to STD - AUTOMATIC and set a vibration level of 7 G's on the VIB Meter. Set the Oscillator Voltage to compress 20 DB by increasing the output voltage control as you observe the B & K meter switched to the Oscillator Voltage position.

9. Manually switch to FILTER 2 and set the oscillator dial to 5 KC. Connect the capacitor decade box or hand-selected capacitors across the FILTER 2 OPTIMIZING jacks on the SD21.

10. Step the 10 DB switch and adjust capacitor value until optimum response is obtained.

11. Manually select FILTER 1 and set oscillator dial to a frequency slightly below the crossover point.

12. Switch the step function switch to -10 DB position and observe the recovery characteristics on an Oscilloscope (Figure 6).

13. Connect a capacitor decade box or hand-selected capacitors across the FILTER 1 OPTIMIZING jacks on the SD21. Repeatedly step the 10 DB switch and adjust the value of this externally connected capacitor until the optimum response is obtained.

14. Place Dynamic Analyzer filter selector on AUTO and adjust band-switching to actuate at desired crossover frequency and check operation and response. This completes the optimizing procedure for sinewave vibration testing.

Example: Optimize a B & K 1038 with a 10 CPS filter and a 100 CPS filter.

1. Install 10 CPS filter in FILTER 1 position and 100 CPS filter in FILTER 2 position. We can expect 80 DB/SEC and 800 DB/SEC maximum compressor speeds respectively from the two filters (8 × BW).

2. Using chart (Figure 9) we see we can optimize the 100 DB/SEC range to 80 DB/SEC and get optimum response to 300 CPS; therefore, we will plan to switch from the 10 CPS to the 100 CPS filter at 300 CPS.

3. Next connect the interconnecting cable between the SD21 and the B & K Oscillator.

4. Manually select the narrow filter and make the test setup shown in Figure 5. Set 10 DB step switch to 0 DB position.

5. Calibrate Analyzer on the narrow filter, then switch to the broader filter and adjust ONLY the FILTER NORMALIZING potentiometer until the meter reads 7. Do not readjust the FREQ control when switched to FILTER 2.

6. (a) Set B & K Compressor OFF.

   (b) Dynamic Analyzer to 0.1-volt RANGE, Meter MULTIPLIER to 1.0. Set FILTERED SIGNAL OUTPUT control full counterclockwise.

   (c) Adjust B & K output voltage control until a reading of 70 MV (Equivalent to 7 G'S with a pickup sensitivity of 10 MV RMS/peak G) is obtained on the SD101A meter.

(d) Adjust the Dynamic Analyzer's FILTERED SIGNAL OUTPUT potentiometer for a reading of 7 G's or, if this proves difficult, to 70 G's reading on the B & K Vibration Meter.

7. Set B & K on STD-AUTOMATIC mode of operation.

8. Set B & K to 5 KC and select FILTER 2 position.

9. Connect approximately 0.2 MFD across the FILTER 2 OPTIMIZING jacks and pulse system with step attenuator and adjust the capacitor value until optimum response is obtained. (Should be around 0.5 MFD.)

10. Select FILTER 1 and adjust oscillator frequency to 250 CPS.

11. Switch the step attenuator switch and observe the recovery envelope on an oscilloscope.

12. Connect approximately 1 MFD across the FILTER 1 OPTIMIZING jacks.

13. Pulse the system using the step attenuator, and adjust the capacitor value until optimum response is obtained. (Should be around 2 MFD.)

14. Set B & K to 300 CPS and adjust the CROSSOVER ADJ potentiometer for actuation. Actuation is indicated by the amber crossover light on top of the SD21. It will be on when FILTER 2 is selected.

The system is now optimized.

2-4. OPTIMIZING PROCEDURE FOR LING S-11 SERVO.

The S-10 Servo Control Amplifier houses the basic servo compressor speed circuit. The compressor speed functions are brought to a front panel switch labeled, NORMAL, BELOW 10 CPS and OFF.

As observed in Figure 10, the smoothing circuit establishes the compressor speed. In the NORMAL position the 4 MFD (C3) capacitor in combination with R64 forms the RC smoothing circuit. In the BELOW 10 CPS position, a 10 MFD capacitor (C2) is switched in parallel with the 4 MFD capacitor. Utilizing the SD21 control relays, the compressor speed can be switched coincident with filter bandwidth switching. Figure 11 schematically shows the control circuit connections to the S-10 control amplifier for controlling and optimizing the servo.

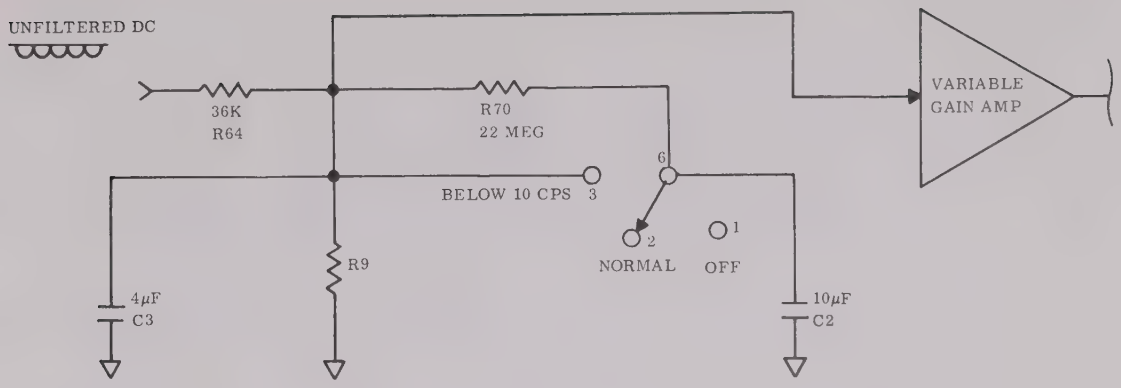


Figure 10. Schematic Representaton of Ling S-11 Servo

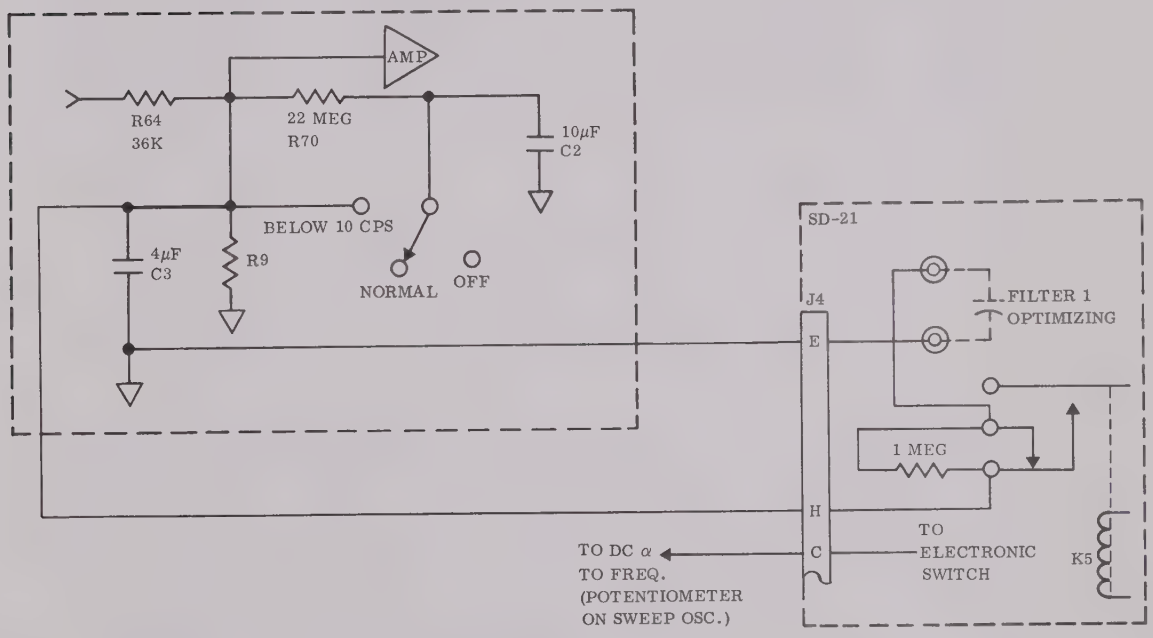


Figure 11. Schematic showing connections of Ling S-11 Servo to SD21

Optimizing Procedure:

1. Adjust value of Optimizing Capacitor (shown in dotted lines, Figure 11) at 3 KC until proper response is obtained (Figure 6 and read previous section on optimizing the B & K Oscillator).

2. Set desired frequency crossover point for SD21.

2-5. OPTIMIZING PROCEDURE FOR LING S-14 SERVO.

No control connections are required to the S-14 Servo.

Procedure:

1. Make test setup shown in Figure 5 and set in an arbitrary vibration level using servo. Set servo to compress approximately 20 DB.

2. At highest frequency prior to SD21 switching, adjust R-15 (on chassis of C-41 Control Amplifier) for desired system response (Figure 6).

3. Tune Sweep Oscillator to 3 KC with wide filter selected and re-adjust R-15 if necessary for optimum system performance.

2-6. OPTIMIZING PROCEDURE FOR B & K MODEL 1019 OSCILLATOR

The compressor circuit in the B & K Model 1019 Servo Cycling Oscillator differs from that in the B & K Model 1018/1038 mainly by the fact that resistors instead of capacitors are being switched in the compressor circuit. This changes the optimizing procedure associated with the SD21 for Sine Wave and Sine Random Vibration Testing as discussed below:

SINE WAVE VIBRATION TESTING

Follow the example outlined on page 16 except:

1. Step 9 - For a 100 cycle filter, use a 3.0 MFD capacitor instead of the 0.2 MFD capacitor.

2. Step 12 - Delete . . . . . The 3.0 MFD capacitor used in Step 9 optimizes for both the 10 and 100 cycle filters.

SINE-RANDOM VIBRATION TESTING

When using the SD21 for optimizing the B & K Model 1019, perform the following:

1. Select FILTER 1 (Narrow Filter) in the Dynamic Analyzer.

2. Select the "HIGH Q" compressor position on the B & K 1019.

3. Use the 3.0 MFD capacitor plugged into the FILTER 2 position when using a 10 cycle filter. This optimizes the B & K for proper operation over the frequency range of 5 cycles to 5 KC.

NOTE

The narrow filter is required to operate over the entire frequency range in SINE-RANDOM testing since a wider filter would allow too much random energy to get into the B & K compressor circuit.

SECTION III

USE OF SD21 IN POWER SPECTRAL DENSITY ANALYSIS

3-1. GENERAL DISCUSSION.

The SD21 is utilized in PSD application to perform Automatic Bandwidth Switching, Automatic Bandwidth Division and Automatic Time Averaging for the two filters located in the Dynamic Analyzer.

The SD21 automatically switches between the filters in the analyzer at predetermined frequency within the frequency range of the sweep oscillator. Therefore, it is now possible to investigate and analyze random signals at the low end of the spectrum with narrow band resolution and with wideband resolution at the high end. This capability not only improves the statistical accuracy of PSD estimates, but it also reduces the time required to scan the spectrum.

However, since more energy is contained in the broad filter than the narrow filter, an offset would normally occur in the DC output when switching between the filters. Therefore, automatic bandwidth division is provided in the SD21 to compensate for the different bandwidths.

Also, the required Averaging Time Constant for each filter is different, Thus, as the filters are automatically selected at some preset frequency, the plug-in averaging capacitor, associated with each filter, is also selected automatically. The VAR TIME CONSTANT ADJ potentiometer on the SD21 allows a variable control of the RC constant used. Figure 12 is a simplified schematic diagram of the Time Averaging circuit.

3-2. STATISTICAL QUALITY OF PSD MEASUREMENTS[1]

Since the measurement of Power Spectra of a random signal is basically dealing with a statistical process, one of the fundamental questions asked is how accurate is the measurement in a statistical sense. One measure of the statistical quality has to do with the number of statistical degress of freedom of the measurement. The number of statistical degrees of freedom is related to the number of samples per second and the duration of the samples, and thus the total number of samples that a PSD estimate is based on at a given frequency is:

$$n = 2BT = 4\,BRC$$

(1)See pages 7-9 through 7-39, ASD Technical Report 61-123, The Application of Statistics to the Flight Vehicle Vibration Problem, December 1961, Aeronautical Systems Division, Air Force Systems Command, U.S. Air Force, Wright-Patterson Air Force Base, Ohio

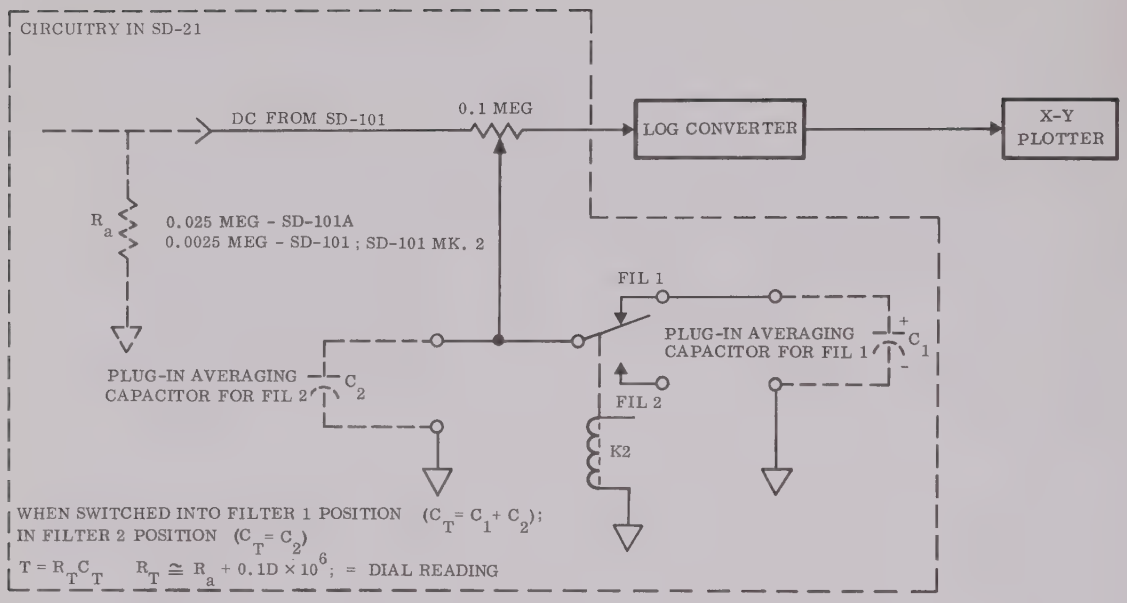

CIRCUITRY IN SD-21
DC FROM SD-101
0.1 MEG
LOG CONVERTER
X-Y PLOTTER
R a
0.025 MEG - SD-101A
0.0025 MEG - SD-101 ; SD-101 MK. 2
FIL 1
PLUG-IN AVERAGING CAPACITOR FOR FIL 1
C 1
PLUG-IN AVERAGING CAPACITOR FOR FIL 2
C 2
FIL 2
K2
WHEN SWITCHED INTO FILTER 1 POSITION (C T = C 1 + C 2);
IN FILTER 2 POSITION (C T = C 2)
T = R T C T R T ≅ R a + 0.1D × 10 6 ; = DIAL READING

Figure 12. Simplified Schematic Diagram Illustrating Variable Time Average Mode

Where:

n = Number of degrees of freedom

B = Filter Bandwidth = Number of samples per second

RC = Averaging time constant of an RC integrator = Duration of samples

T = Tape loop length in seconds = Duration of samples

The higher "n" becomes, the more accurate (in a statistical sense) any given power density measurement becomes. In practice, the accuracy of a PSD plot can be significantly improved by simply pencil-averaging the PSD plot.

Confidence levels, for any discrete measured or plotted point, can be established by referring to the Chi Square Distribution functions shown by the chart in Figure 13. The chart is a plot of the ratio of TRUE MEAN SQUARE (σ^2) level to an OBSERVED MEAN SQUARE (S^2) level as a function of the NUMBER of DEGREES OF FREEDOM (n) and for various CONFIDENCE LEVELS. The chart provides a relative feel for the statistical quality to be expected.

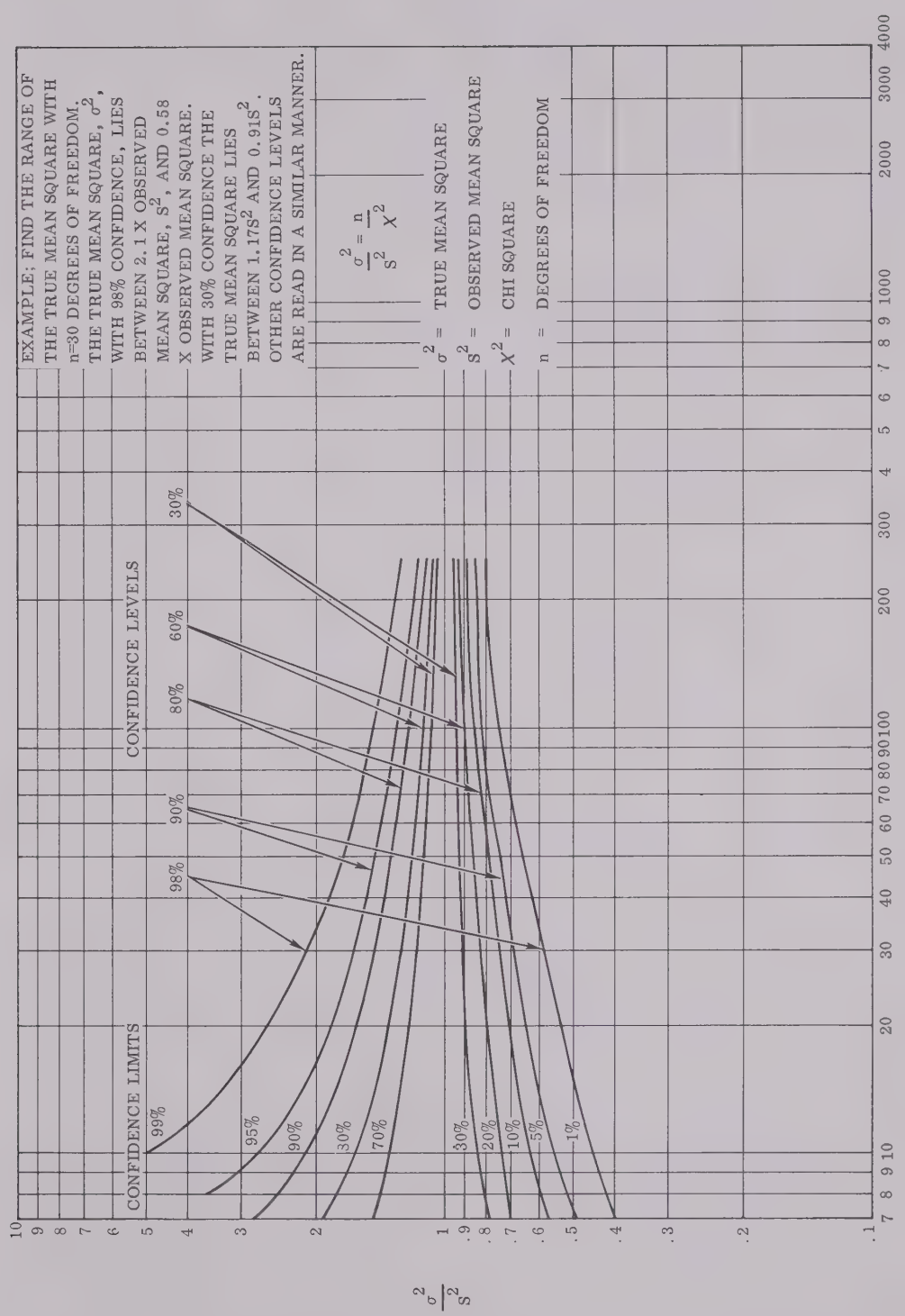

EXAMPLE; FIND THE RANGE OF THE TRUE MEAN SQUARE WITH n=30 DEGREES OF FREEDOM. THE TRUE MEAN SQUARE, σ^2, WITH 98% CONFIDENCE, LIES BETWEEN 2.1 X OBSERVED MEAN SQUARE, S^2, AND 0.58 X OBSERVED MEAN SQUARE. WITH 30% CONFIDENCE THE TRUE MEAN SQUARE LIES BETWEEN $1.17S^2$ AND $0.91S^2$. OTHER CONFIDENCE LEVELS ARE READ IN A SIMILAR MANNER.
$\frac{\sigma^2}{S^2} = \frac{n}{\chi^2}$
σ^2 = TRUE MEAN SQUARE
S^2 = OBSERVED MEAN SQUARE
χ^2 = CHI SQUARE
n = DEGREES OF FREEDOM
CONFIDENCE LIMITS
99%
95%
90%
30%
70%
30%
20%
10%
5%
1%
CONFIDENCE LEVELS
98%
90%
80%
60%
30%
$\frac{\sigma^2}{S^2}$
DEGREES OF FREEDOM n

Figure 13. Chi Square Distribution Chart

3-3. SELECTION OF FILTER BANDWIDTH

If the filter bandwidth is not specified by the agency for whom the PSD analysis is being performed, the operator is faced with selecting a filter which provides:

1. Best resolution of resonances or peaks in the power spectrum, and

2. The desired statistical confidence.

A good rule of thumb to apply is:

$$\text{Analyzer Filter Bandwidth} \leq \frac{\text{BW (Pwr)}}{4}$$

Where:

BW (Pwr) = Half power bandwidth of narrowest resonance or anti-resonance

NOTE

Always use the narrow filter in FILTER 1 position and always make data runs from low frequency to high frequency, since the averaging time constant capacitors are pre-charged going from low to high frequency.

3-4. SELECTION OF AVERAGING TIME CONSTANTS.

The selection of the proper averaging time constant is dependent upon the source of the random data being analyzed. The analysis can be performed ON-LINE, where the amount of data available is unlimited or it can be performed from TAPED DATA where the amount of data is limited by the length of the tape loop. The following discussion covers both types of data:

1. On-Line Data

Once the filter bandwidth has been selected (see paragraph 3-3), the Averaging Time Constant is determined by selection of the statistical accuracy desired:

$$n = 4 \text{ BRC}$$

Where:

n = Number of degrees of freedom

B = Effective Squared Bandwidth of Analyzer Filter (CPS)

RC = Averaging Time Constant (SEC)

Therefore:

$$RC = \frac{n}{4B}$$

It is generally acceptable to set "n" within the 60 to 240 range. However, "n" can be made as high as desired, providing the analysis time is increased accordingly. Refer to selection of sweep rate discussion in paragraph 3-5.

2. Taped Data

The Averaging Time Constant is determined by selection of the statistical accuracy which in turn is controlled by the tape loop length:

$$n = 2BT$$

Where:

T = Tape Loop Length (in seconds)

Therefore, to preserve "n" an optimum RC must be selected. From the case of ON-LINE DATA, the equation n = 4 BRC can be equated to the present case to obtain an expression for the optimum Averaging Time Constant:

$$n = 4BRC = 2BT$$

Therefore:

$$RC = \frac{T}{2} = \frac{n}{4B}$$

Thus, to preserve "n" available from the tape loop, RC must be selected to equal T/2. Using a longer RC time constant will not increase the statistical accuracy but a shorter RC time constant will result in less statistical accuracy.

3-5. SELECTION OF SWEEP RATE.

The frequency spectrum must be swept slow enough to allow both the Analyzer Filter and Averaging Time Constant (RC) to respond properly. Since approximately 4 RC Time Constants are required for an RC circuit to achieve 98% of its final output, the rate of change of data level in the filter must not exceed 4 RC. Therefore, the sweep

rate must be selected that will allow the energy within the filter to be sampled for 4 RC seconds. Thus, the equations:

$$\text{Sweep Rate} \leq \frac{B}{4RC}$$

and since:

$$RC = T/2$$

$$\text{Sweep Rate} \leq \frac{B}{2T}$$

Another criteria governing sweep rate is:

$$\text{Sweep Rate} \leq \frac{B^2}{8}$$

This figure is based on the response characteristics of an ideal filter and is conservative when applied to real filters.

Therefore:

$$\text{Sweep Rate (ON-LINE DATA)} \leq \frac{B}{4\,RC} \quad \text{or} \quad \frac{B^2}{8}, \text{ whichever is smaller.}$$

$$\text{Sweep Rate (TAPED DATA)} \leq \frac{B}{2T} \quad \text{or} \quad \frac{B^2}{8}, \text{ whichever is smaller.}$$

Therefore, the total analysis time on the basis of a linear sweep rate would be:

$$A_t = \frac{\text{Total Analysis Frequency Range (CPS)}}{\text{Sweep Rate (CPS)}}$$

A_t = Total Analysis Time (SEC)

Since the oscillators principally used to drive the SD101A sweep at a logarithmic rate, two approaches may be taken:

(1) Scan the frequency range at a logarithmic rate set to cover the frequency range in the same average total analysis time (A_t), or

(2) Break down the frequency range into four or five parts, adjusting the sweep rate so as to approach a linear sweep rate calculated above.

Generally, (1) is used when analyzing structural responses. Since the bandwidth of a given resonance is proportional to Q, and assuming that each resonance exhibits a constant Q based on the highest observed Q, the rate of change of data in the filter and RC averaging circuit would tend to change at the same rate using a logarithmic sweep.

$$Q = \frac{\text{Resonance frequency (CPS)}}{\text{Resonance bandwidth (CPS)}}$$

Approach (2) is generally used when expecting more discreet spectral lines or resonance characteristics approaching constant bandwidth, such as analyzing the output of a multi-filter Automatic Equalizer Analyzer. Therefore, to set the oscillator sweep rate in degrees/minute for (1):

$$\text{Oscillator sweep rate (DEG/MIN)} = \frac{\text{total analysis freq. range (DEG)}}{\text{total analysis time } (A_t) \text{ (MIN)}}$$

$$\frac{A_t}{60} = \text{total analysis time (minutes)}$$

The total analysis time in degrees can be read directly off the oscillator frequency dial.

3-6. PSD CALIBRATION PROCEDURE.

PSD Analysis using the SD21 is performed by the following procedure:

A. Establish the test conditions:

1. Is the analysis to be performed ON-LINE or from tape?
2. If tape is used, what is the length of the tape loop (in seconds)?
3. What is the frequency range of analysis?
4. What is the calibrated pickup sensitivity in MV(RMS)/G(RMS)?
5. Which test setup will be used for the analysis? (See paragraphs 3-7, 3-8, and 3-9.)

B. Select the filter bandwidths (see paragraph 3-3): Plug the narrow filter into FILTER 1 position and broad filter into FILTER 2 position.

C. Statistical Degrees of Freedom (n):

1. For ON-LINE Analysis, select n = 60 to 240.

2. For tape analysis calculate "n" using the following equation:

$$n = 2BT$$

where: B = filter bandwidth

T = Tape length (in seconds)

D. Compute Averaging Time Constants:

1. Compute Narrow Filter Time Constant (T_{f_1})

TAPE: $T_{f_1} = R_T (C_1 + C_2) = T/2$

where: T = Tape loop length (in seconds)

ON-LINE: $T_{f_1} = R_T (C_1 + C_2) = \frac{n}{4B}$

where: B = narrow filter bandwidth

2. Compute Broad Filter Time Constant (T_{f_2}):

$$T_{f_2} = R_T C_2 = \frac{n}{4B}$$

where: B = broad filter bandwidth

3. Compute Variable Time Constant Adjust:

Select a convenient value of capacitance for C_2, the averaging capacitor for the broad filter, and calculate the dial setting (D) position of the VAR TIME AVE ADJ potentiometer on the SD21 by using the following equation:

$$D = \frac{T_{f_2} - R_a C_2}{(0.1 \times 10^6) C_2}$$

where: R_a = terminating resistance of analyzer
= 0.025×10^6 for SD101A
= 0.0025×10^6 for SD101 and SD101 MK 11

Plug C_2 into J2 and set VAR TIME AVE ADJ on SD-21.

4. Compute Narrow Filter Averaging Capacitor (C_1):

$$C_1 = \frac{T_{f_1}}{R_a + (0.1 \times 10^6)\ D} - C_2$$

Plug C_1 into J3 on SD-21.

E. Compute and Calibrate Analyzer for the Proper Bandwidth Division

1. Select FILTER 1 and adjust the analyzer for a meter indication of 7.

2. Select FILTER 2 and adjust FILTER 2 NORMALIZING potentiometer for a meter indication of:

$$\frac{K_2 \sqrt{BW_1}}{K_1 \sqrt{BW_2}} \times 7 = \text{meter reading}$$

where: K_1 = Detector Constant FILTER 1

K_2 = Detector Constant FILTER 2

BW_1 = Narrow filter effective squared bandwidth

BW_2 = Broad filter effective squared bandwidth

NOTE

See paragraphs 3-7, 3-8 and 3-9 to obtain K values for the various filters and variations between analyzers.

F. Calculate the sweep rate (SR), total analysis time (A_t) and the sweep rate SR (DEG/MIN), by following equations:

1. $SR = B/4RC$

2. $A_t = \frac{\text{Upper freq} - \text{Lower freq}}{SR}$

3. $SR = \left(\frac{DEG}{MIN}\right) = \frac{\text{Total Degrees of Dial Movement}}{SR}$

G. Calibrate the PSD system per the procedure outlined in paragraphs 3-7, 3-8 or 3-9 depending upon the setup selected.

3-7. SETUP #1 CALIBRATION PROCEDURE.

PSD Analysis, using equipment setup as shown in Figure 14, is applicable to the SD101, SD101 Mark II, and SD101A. However the calibration procedure differs slightly between the SD101A and the other two Dynamic Analyzers. The following procedure is applicable to all three except where noted:

CONTROL KNOB SETTINGS:

1. DYNAMIC ANALYZER

   (a) Set RANGE and MULTIPLIER controls to CAL.

   (b) Select filter one (1).

   (c) Adjust FREQ for peak indication on meter.

   (d) Adjust FILTER 1 NORMALIZING potentiometer for meter reading of 7.

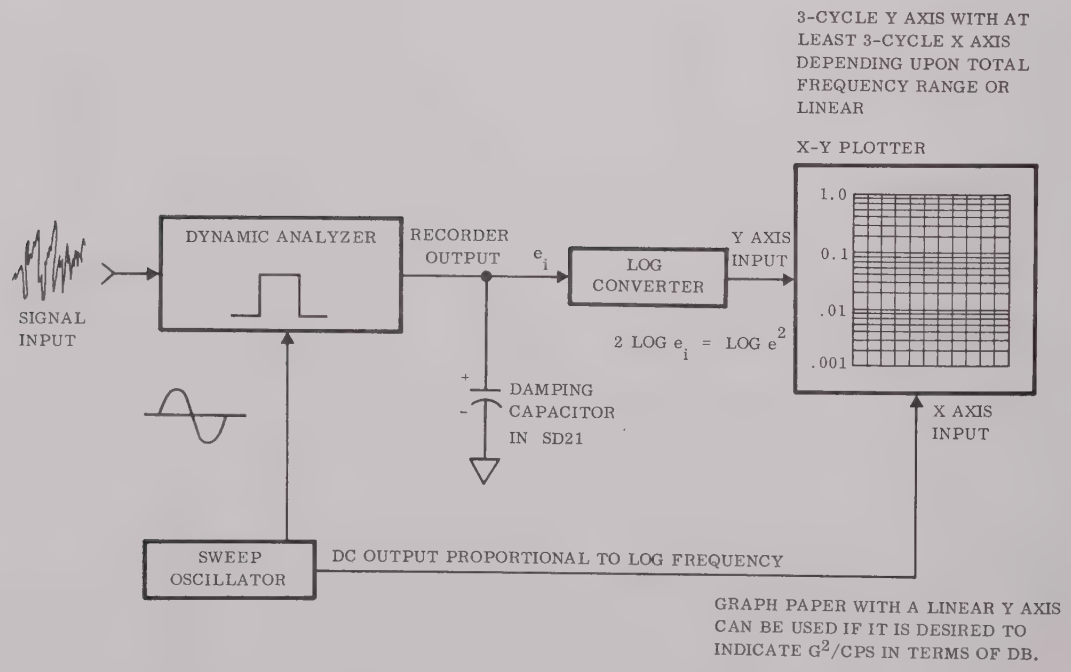

3-CYCLE Y AXIS WITH AT LEAST 3-CYCLE X AXIS DEPENDING UPON TOTAL FREQUENCY RANGE OR LINEAR
X-Y PLOTTER
1.0
0.1
.01
.001
SIGNAL INPUT
DYNAMIC ANALYZER
RECORDER OUTPUT
e_i
LOG CONVERTER
Y AXIS INPUT
2 LOG e_i = LOG e^2
DAMPING CAPACITOR IN SD21
X AXIS INPUT
SWEEP OSCILLATOR
DC OUTPUT PROPORTIONAL TO LOG FREQUENCY
GRAPH PAPER WITH A LINEAR Y AXIS CAN BE USED IF IT IS DESIRED TO INDICATE G^2/CPS IN TERMS OF DB.

Figure 14. Setup #1 PSD Analysis System

(e) Turn RECORDER OUTPUT control fully clockwise.

2. LOG CONVERTER (Assuming a Moseley Log Converter)

(a) Set to DC mode.

(b) Set ZERO DB on input attenuator.

(c) Set 5 DB/IN on OUTPUT SCALE FACTOR.

3. CALIBRATION OF LOG CONVERTER TO PLOTTER

For log e_i, leave controls as previously set in 1 and 2.

(a) Turn Plotter on and set ZERO control for a reading on the chart.

(b) Set Log Converter INPUT ATTENUATOR to 10 DB and set the Plotter ZERO control for a reading of 0.1 (assuming, for the moment, that 1 is at the top of the chart).

(c) Set Log Converter back to 0 DB and adjust Plotter GAIN for a reading of 1 on the chart.

(d) Set the Log Converter to 10 DB and reset the Plotter ZERO to 0.1.

(e) Set the Log Converter to 0 DB and adjust the GAIN for a reading of 1.

(f) Continue repeating this procedure until the 10 DB range changes on the Log Converter producing a 10 to 1 or 20 DB or 1 cycle change on the chart. When this is accomplished, the Log Converter is calibrated to the Plotter for 2 log e_i, which is an identity for log e^2. Dividing by bandwidth is nothing more than changing the Plotter ZERO.

4. CALIBRATION SIGNAL

The Dynamic Analyzer is providing the calibration signals from an internal standard. The CAL equivalent is derived as follows:

$$\text{Full Scale} = \frac{\text{Range (MV)} \times \text{Multiplier setting}}{\text{Pickup Sensitivity (MV/G)}} = \text{G's full scale}$$

NOTE

The effective squared bandwidth of a Spectral Dynamics Filter is very close to the half power bandwidth.

SD101 and SD101 Mark II

$$CAL = \frac{(0.84 \text{ Full Scale})^2}{\text{effective squared filter bandwidth}}$$

1.2 is a constant of proportionality between the DC output of the SD101 and true RMS with a random input. The 1.2 was determined by calibrating a true RMS meter connected to the filter signal output from the SD101, and a DC VTVM or plotter connected to the DC output of the SD101 to read the same value on a sine wave. Then a comparison was made between the TRMS meter and DC output levels with random applied to the SD101. 1.2 is equal to the RMS meter reading/DC output reading.

Since the SD101 meter on CAL is set to 0.7 full scale as a reference line, then $0.7 \times 1.2 = 0.84$ full scale for the true RMS level when measuring the random signal.

Example: A pickup sensitivity of 10 MV/G, 20 CPS filter in SD101 and an anticipated operating level of 8 G's RMS from the shaker.

Note: The RMS voltage setting of the RANGE control must not be exceeded. (8 G's × 10 MV = 80 MV allowing the SD101 to be operated on the IV scale).

Using the above:

$$\text{Full Scale} = \frac{100 \text{ MV} \times 1}{10 \text{ MV/G}} = 10 \text{ G's}$$

$$CAL = \frac{(0.84 \times 10)^2}{17.6} = \frac{70.6\,G^2}{17.6} = \frac{4G^2}{CPS}$$

SD101A

$$CAL = \frac{(0.7K \text{ Full Scale})^2}{\text{effective squared filter bandwidth}}$$

K is a constant of proportionality between the DC output of the SD101A and true RMS with a random input. K changes slightly with the filter bandwidth due to the characteristics of the detector in the SD101A. K was determined by calibrating a true RMS meter connected to the filtered signal output from the SD101A, and a DC VTVM or plotter connected to the DC output of the SD101A to read the same value on a sine wave. Then a comparison was made between the TRMS meter and DC output levels with random applied to the SD101A. K is equal to the RMS meter reading/DC output reading.

K Factors (Test Setup 1 only)

Bandwidth	2	5	10
K Factor	1.15	1.16	1.18

Bandwidth	20	50	100
K Factor	1.04	0.968	0.85

Note: K = 1.13 for all filters used in SD101A (S/N 260 and on) Dynamic Analyzers.

Using Meter: K = 1.2 for all filters

Since the SD101A meter on CAL is set to 0.7 full scale as a reference line, then CAL = 0.7K full scale for the true RMS level when measuring the random signal.

Example: A pickup sensitivity of 10 MV/G, 20 CPS filter in SD101A and an anticipated operating level of 8 G's RMS from the shaker.

Using the above:

$$\text{Full Scale} = \frac{100 \text{ MV} \times 1}{10 \text{ MV/G}} = 10 \text{ G's}$$

SD101 and SD101 Mark II (Continued)

(a) Set the Plotter ZERO to 4 in the upper portion of the chart and the system is calibrated with that point representing $4G^2/CPS$.

(b) Set the SD101 RANGE and MULTIPLIER to 0.1 and 1.0, respectively, and the system is ready to operate.

(c) If it is desired to make the same point on the chart $0.4\ G^2$ CPS instead of $4G^2$ CPS, change the MULTIPLIER setting from 1.0 to 0.3 This increases the SD101 sensitivity 10 DB which produces a 20 DB increase in the Plotter sensitivity.

NOTE

The .03 and .3 positions of the MULTIPLIER switch are abbreviated values. Therefore, in order to arrive at accurate results in PSD calculations, the actual figures that should be used for calculation of Full Scale Calibration Signal are .0316 or .316, depending on the setting of the switch.

SD101A (Continued)

K for 20 CPS Filter = 1.04

$$CAL = \frac{(0.7 \times 1.04 \times 10)^2}{20} = \frac{52.9\,G^2}{20} = \frac{2.65\,G^2}{CPS}$$

(a) Set the Plotter ZERO to 2.65 in the upper portion of the chart and the system is calibrated with that point representing $2.65\ G^2/CPS$.

(b) Set the SD101A RANGE and MULTIPLIER to 0.1 and 1.0, respectively, and the system is ready to operate.

(c) If it is desired to make the same point on the chart $0.265\ G^2/CPS$ instead of $2.65\ G^2/CPS$, change the MULTIPLIER setting from 1.0 to 0.3 and you have increased the SD101A sensitivity to 10 DB which produces a 20 DB increase in the Plotter sensitivity.

NOTE

Setup #1 can also be used as follows: By-passing the Log Converter and then squaring the resulting plot manually.

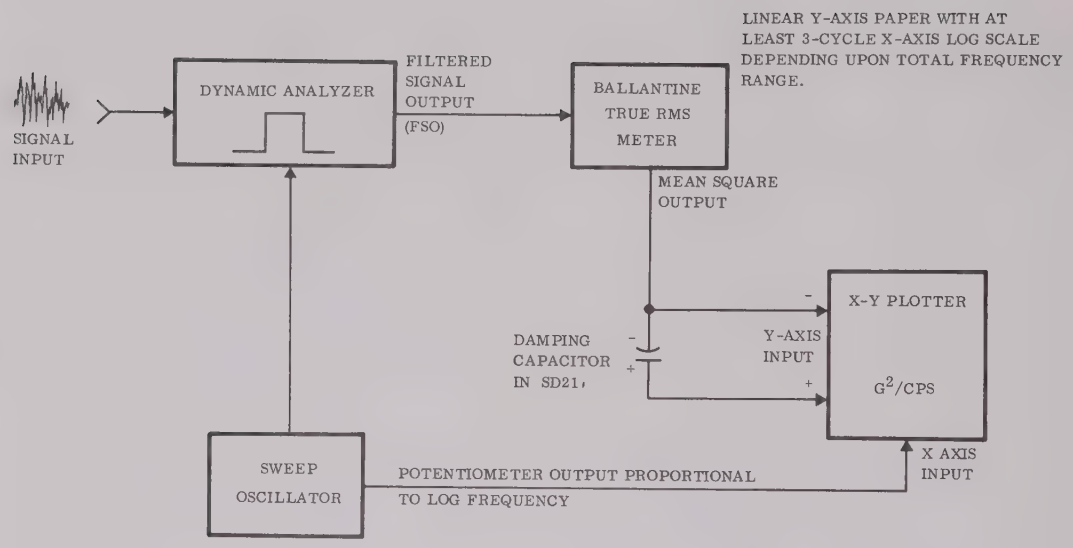


Figure 15. Setup #2, PSD Analysis System

3-8. SETUP #2 CALIBRATION PROCEDURE.

CONTROL KNOB SETTING:

1. DYNAMIC ANALYZER

   (a) RANGE and MULTIPLIER controls to CAL.

   (b) Select FILTER 1.

   (c) Adjust FREQ for peak indication on meter.

   (d) Set FILTER 1 NORMALIZING potentiometer for meter reading of 7.

   (e) Adjust FSO for a meter reading of 7 volts on the Ballantine (the MEAN SQUARE OUTPUT plug cannot be inserted during this adjustment).

2. CALIBRATION OF PLOTTER TO BALLANTINE

   (a) Use Linear Y Scale.

(b) Turn Plotter on and adjust Y ZERO for an on-scale indication. (Plug in MEAN SQUARE OUTPUT.)

(c) Change the Ballantine ATTENUATOR 10 DB to a higher scale (less sensitive range).

(d) Set the Plotter ZERO to 0.1 of the desired full-scale deflection.

(e) Turn the Ballantine attenuator to its original position (10 DB more sensitive) and adjust the GAIN of the Plotter for full scale).

(f) Repeat steps (c), (d), and (e), until a 10-DB change in the attenuator produces a 10 to 1 (20 DB) change in the Recorder deflection.

3. $$\text{CAL} = \frac{(0.7 \text{ Full Scale})^2}{\text{Effective square filter bandwidth}}$$

$$\text{Full Scale} = \frac{\text{SD-101 Range (MV)}}{\text{Pickup Sensitivity (MV/G)}}$$

Example: P/U Sensitivity $= \frac{10 \text{ MV}}{\text{G}}$ Full Scale $= \frac{100 \text{ MV}}{10 \text{ MV/G}} = 10 \text{ G}$

10 G's (RMS) operating level - 20 CPS filter

$$\text{CAL} = \frac{(0.7 \times 10)^2}{20} = \frac{49 \text{ G}^2}{20 \text{ CPS}} = 2.45 \text{ or } 2.5 \text{ G}^2/\text{CPS}$$

NOTE

Only the RANGE control has any effect on the filtered output. This is why the MULTIPLIER does not enter into the calculation. During operation, if it is desired to increase the sensitivity 10 to 1, change the Ballantine attenuator 10 DB to a more sensitive scale. Setup #2 can be used to plot out the squared response of the filters.

3-9. SETUP #3 CALIBRATION PROCEDURE.

1. CONTROL KNOB SETTINGS

The setup and calibration procedure is basically the same as for Setup #1. The differences are as follows:

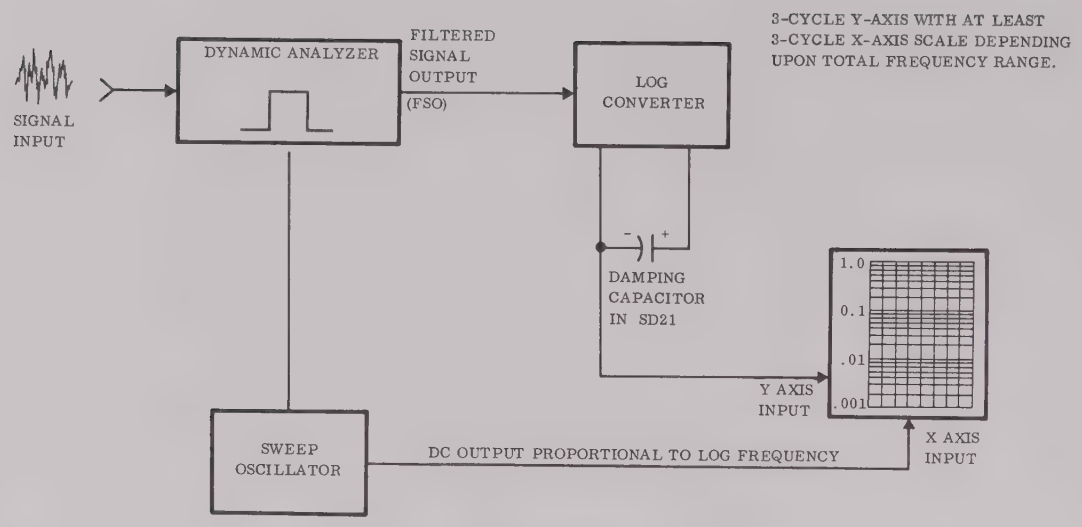


Figure 16. Setup #3, PSD Analysis System

(a) Operate the Log Converter in the AC mode.

(b) The lower frequency limit is 20 CPS due to the frequency response of the Log Converter.

(c) K is constant of proportionality between RMS and Log Converter output and depends on filter bandwidth.

$$\text{CAL} = \frac{(0.7\,\text{K full scale})^2}{\text{Effective squared bandwidth}}$$

$$\text{Full Scale} = \frac{\text{SD-101 Range (MV)}}{\text{Pickup sensitivity (MV/G)}}$$

Filter BW (CPS)	K
2	1.15
5	1.13
10	0.944
20	0.920
50	0.868
100	0.870

NOTE

The FILTERED SIGNAL OUTPUT is capable of delivering 7 volts into the Log Converter. Adjust the output until the Log Converter meter is indicating approximately 5 DB.

NOTE

Setup #3 is normally used when the chopper in the Log Converter is not functioning or wider dynamic range is required for plotting RMS G/CPS levels.

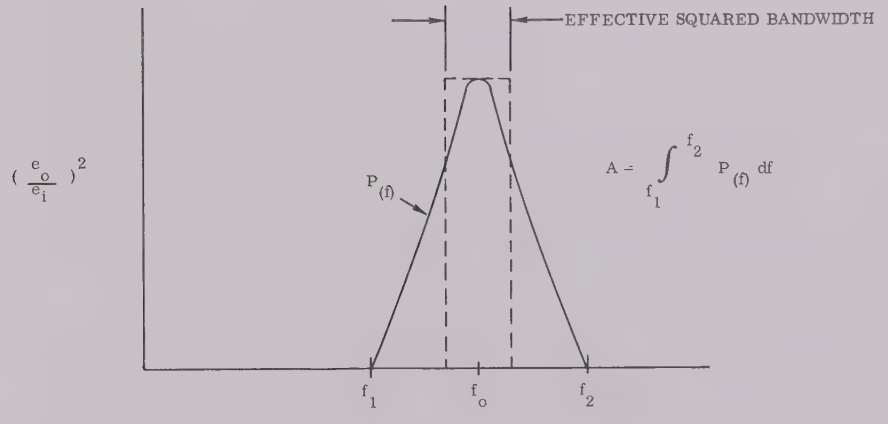


Figure 17. Calculation of Effective Squared Bandwidth

2. Procedure for Obtaining the Effective Squared Bandwidth of Filter.

(a) Plot the squared response characteristics of the filter on the linear paper.

(b) Integrate the curve to find the total area.

(c) Construct a rectangle of the same height containing the same area. The width of the rectangle is the effective squared bandwidth.

3-10. ON-LINE DATA ANALYSIS EXAMPLE CALIBRATION.

The following example illustrates the procedure for performing Power Spectral Density Analysis of ON-LINE data using an SD101A Dynamic Analyzer and the SD21 Automatic Bandwidth Switching Adapter:

A. Test Conditions:

1. An analysis will be performed directly from an accelerometer signal in a random vibration test.

2. Frequency Range to be analyzed = 20 to 3,000 CPS.

3. Total test level = 10 G (RMS).

4. Pickup Sensitivity = 10 MV (RMS)/G (RMS).

B. Selection of Filter Bandwidth (see paragraph 3-3).

For this example, a 5-CPS filter will be used in the frequency range of 20 to 100 CPS and a 20-CPS filter will be used in the frequency range of 100 to 3,000 CPS.

C. Calculation of Statistical Degrees of Freedom (see paragraph 3-2).

Since n = 4BRC, we must choose a practical figure in the range of 60 to 240 degrees and proceed with the calibration. For this example we will select n = 100 degrees.

D. Calculation of Averaging Time Constants (see paragraph 3-4).

1. 5-CPS filter:

Let T_{f_1} = RC Time Constant for 5-CPS filter

$$T_{f_1} = R_T(C_1 + C_2) = \frac{n}{4B} = \frac{100}{20} = 5 \text{ SECONDS}$$

2. 20-CPS filter:

Let T_{f_2} = RC Time Constant for 20-CPS filter

$$T_{f_2} = R_T C_2 = \frac{n}{4B} = \frac{100}{80} = 1.25 \text{ SECONDS}$$

3. Variable Time Constant Adjust:

We have a 10 MFD, 3V capacitor available, so we will use it for C_2 which plugs into J2 on the SD21. We then calculate the dial setting for the Variable Time Averaging:

$$\text{Dial Setting} = D = \frac{T_{f_2} - R_a C_2}{(0.1 \times 10^6) C_2} = \frac{1.25 - (0.025 \times 10)}{1} = 1$$

Therefore we adjust the VAR TIME AVE ADJ knob to the 1 position.

4. Calculate (C_1), Capacitor Value for the 5-CPS Filter:

$$C_1 = \frac{T_{f_1}}{R_a + (0.1 \times 10^6) D} - C_2 = \frac{5}{(0.025 + 0.1) \times 10^6} - 10 \times 10^{-6} = \frac{5}{0.125} - 10 \times 10^{-6} = 30 \text{ MFD}$$

C_1 plugs into J3 on the SD21.

The Averaging Time Constants have now been set for both filters.

E. Calculate and Calibrate for Proper Bandwidth Division:

The next step is to normalize the output of FILTER 2 with FILTER 1.

1. Select FILTER 1 and calibrate the analyzer for a meter indication of 7.

2. Select FILTER 2 and adjust the FILTER 2 NORMALIZING potentiometer to read:

$$\frac{\sqrt{\frac{\text{Effective squared BW of Narrow Filter}}{K_1}}}{\sqrt{\frac{\text{Effective squared BW of Broad Filter}}{K_2}}} \times 7 = \frac{\sqrt{\frac{5}{1.16}}}{\sqrt{\frac{20}{1.04}}} \times 7 = 0.448 \times 7 = 3.14$$

where: K is the constant of proportionality between the DC output and the true RMS random input. See paragraphs 3-7, 3-8 and 3-9 for appropriate K values.

NOTE

This example is for an SD101A having a serial number less than 260. Otherwise K_1 would be equal to K_2.

NOTE

Do not adjust the FREQUENCY control on the analyzer.

NOTE

Each filter is accompanied by a filter plot, the measured half-power (or 3 DB) bandwidth. The 3-DB bandwidth shown on the plot may be used as a close approximation or the effective squared bandwidth may be measured from the plots. If we have used the effective squared bandwidth in our calculations above, there will be little change in the recorder output at the time the filters switch.

F. Selection of Sweep Rates (see paragraph 3-5 for details).

We must now calculate the proper sweep rate for each filter, total analysis time required and then set the scan rates.

1. Sweep Rate = $SR \leq \frac{B}{4RC}$

(a) 5-CPS Filter

$$SR \leq \frac{5}{20} \leq 0.25 \text{ CPS/SEC}$$

(b) 20-CPS Filter

$$SR \leq \frac{20}{5} \leq 4 \text{ CPS/SEC}$$

2. Analysis Time = $A_t = \frac{\text{Upper Freq - Lower Freq}}{SR}$

(a) 5-CPS Filter

$$A_t = \frac{100 \text{ CPS} - 20 \text{ CPS}}{0.25 \text{ CPS/SEC}} = \frac{80}{0.25} = 320 \text{ SEC}$$

(b) 20-CPS Filter

$$A_t = \frac{(3000 - 100)\ \text{CPS}}{4\ \text{CPS/SEC}} = \frac{2900}{4} = 725\ \text{SEC}$$

NOTE

At this point, if the analysis time required is too long, we can speed it up by sacrificing statistical quality with the 5-CPS filter.

3. Setting the Oscillator Scan Rates:

Using a log sweep oscillator such as the B & K, the scan rate is set in degrees per minute. Therefore, we must first figure the frequency range and then divide by the analysis time.

(a) Frequency Range = 20 - 100 CPS for 5-CPS filter which is 50 degrees on the B & K dial.

$$\text{Sweep Rate Setting (DEG/MIN)} = \frac{50\ \text{DEG}}{5.3\ \text{MIN}} = 7.4\ \text{DEG/MIN}$$

(b) Frequency Range = 100 - 3,000 CPS for 20-CPS filter which is 107 degrees on the B & K dial.

$$\text{Sweep Rate Setting (DEG/MIN)} = \frac{107\ \text{DEG}}{12\ \text{MIN}} = 8.9\ \text{DEG/MIN}$$

G. Calibrate the Analyzer to the Plotter.

Follow the procedure outlined in paragraph 3-7, Setup #1.

3-11. TAPED DATA ANALYSIS EXAMPLE CALIBRATION.

The following example illustrates the procedure for performing Power Spectral Density Analysis of taped data using an SD101A Dynamic Analyzer and the SD21 Automatic Bandwidth Switching Adapter:

A. Test Conditions:

1. An analysis will be performed on a tape loop recording of a random test.

2. Tape Loop Length = 10 Seconds.

3. Frequency range to be analyzed = 20 CPS to 3,000 CPS.

4. Total recorded test level = 10 G (RMS).

5. Pickup sensitivity = 10 MV (RMS)/G (RMS).

6. Setup #1 has been chosen.

B. Selection of filter bandwidth. (For details, see paragraph 3-3.)

For this example, a 5-CPS and a 20-CPS filter will be used in the frequency range of 100 CPS to 3,000 CPS.

C. Calculation of Statistical Degrees of Freedom (see paragraph 3-2).

1. 5-CPS Filter

$n_1 = 2B_1T = 2 \times 5 \times 10 = 100$ DEGREES

2. 20-CPS Filter

$n_2 = 2B_2T = 2 \times 20 \times 10 = 400$ DEGREES

D. Calculation of Averaging Time Constants (see paragraph 3-4).

Since we have 100 degrees available using the 5-CPS filter and 400 degrees using the 20-CPS filter, we will select our time constants such that we maintain 100 degrees of freedom.

1. Narrow Filter Time Constant

Let T_{f_1} = Time Constant of 5-CPS filter

$T_{f_1} = R_T(C_1 + C_2) = T/2 = \frac{10}{2} = 5$ SECONDS

2. Broad Filter Time Constant

Let T_{f_2} = Time Constant of 20-CPS filter

$T_{f_2} = R_T C_2 = \frac{n}{4B} = \frac{100}{80} = 1.25$ SECONDS

NOTE

The equation $RC = n/4B$ is applied to the broad filter in order to calculate the optimum Time Constant and still maintain 100 degrees of freedom.

3. Variable Time Constant Adjust:

We have a 10 MFD, 3V capacitor available, so we will use it for C_2 which plugs into J2 on the SD21. We then calculate the dial setting for the Variable Time Averaging:

$$\text{Dial Setting} = D = \frac{T_{f_2} - R_a C_2}{(0.1 \times 10^6) C_2} = \frac{1.25 - (0.025 \times 10)}{1} = 1$$

Therefore we adjust the VAR TIME AVE ADJ knob to the 1 position.

4. Calculate (C_1), Capacitor Value for the 5-CPS Filter:

$$C_1 = \frac{T_{f_1}}{R_a + (0.1 \times 10^6) D} - C_2 = \frac{5}{(0.025 + 0.1) \times 10^6} - 10 \times 10^{-6} = \frac{5}{0.125 \times 10^6} - 10 \times 10^{-6}$$

$$= 40 \text{ MFD} - 10 \text{ MFD} = 30 \text{ MFD}$$

C_1 plugs into J3 on the SD21.

The Averaging Time Constants have not been set for both filters.

Calculate and Calibrate for Proper Bandwidth Division:

The next step is to normalize the output of FILTER 2 with FILTER 1.

1. Select FILTER 1 and calibrate the analyzer for a meter indication of 7.

2. Select FILTER 2 and adjust the FILTER 2 NORMALIZING potentiometer to read:

$$\frac{\sqrt{\frac{\text{Effective squared BW of Narrow Filter}}{K_1}}}{\sqrt{\frac{\text{Effective squared BW of Broad Filter}}{K_2}}} \times 7 = \frac{\sqrt{\frac{5}{1.16}}}{\sqrt{\frac{20}{1.04}}} \times 7 = 0.448 \times 7 = 3.14$$

where: K is the constant of proportionality between the DC output and the true RMS random input. See paragraphs 3-7, 3-8 and 3-9 for appropriate K values. If an SD101A S/N 260 and on were used, K_1 would be equal to K_2 in the above example.

NOTE

Do not adjust the FREQUENCY control on the analyzer.

NOTE

Each filter is accompanied by a filter plot, the measured half-power (or 3 DB) bandwidth. The 3-DB bandwidth shown on the plot may be used as a close approximation or the effective squared bandwidth may be measured from the plots. If we have used the effective squared bandwidth in our calculations above, there will be little change in the recorder output at the time the filters switch.

F. Selection of Sweep Rates (see paragraph 3-5 for details).

We must now calculate the proper sweep rate for each filter, total analysis time required and then set the scan rates.

1. Sweep Rate $= SR \leq \frac{B}{4RC}$

(a) 5-CPS Filter

$$SR \leq \frac{5}{20} \leq 0.25 \text{ CPS/SEC}$$

(b) 20-CPS Filter

$$SR \leq \frac{20}{5} \leq 4 \text{ CPS/SEC}$$

2. Analysis Time $= A_t = \frac{\text{Upper Freq - Lower Freq}}{SR}$

(a) 5-CPS Filter

$$A_t = \frac{100 \text{ CPS} - 20 \text{ CPS}}{0.25 \text{ CPS/SEC}} = \frac{80}{0.25} = 320 \text{ SEC}$$

(b) 20-CPS Filter

$$A_t = \frac{(3000 - 100) \text{ CPS}}{4 \text{ CPS/SEC}} = \frac{2900}{4} = 725 \text{ SEC}$$

NOTE

At this point, if the analysis time required is too long, we can speed it up by sacrificing statistical quality with the 5-CPS filter.

3. Setting the Oscillator Scan Rates:

Using a log sweep oscillator such as the B & K, the scan rate is set in degrees per minute. Therefore, we must first figure the frequency range and then divide by the analysis time.

(a) Frequency Range = 20 - 100 CPS for 5-CPS filter which is 50 degrees on the B & K dial.

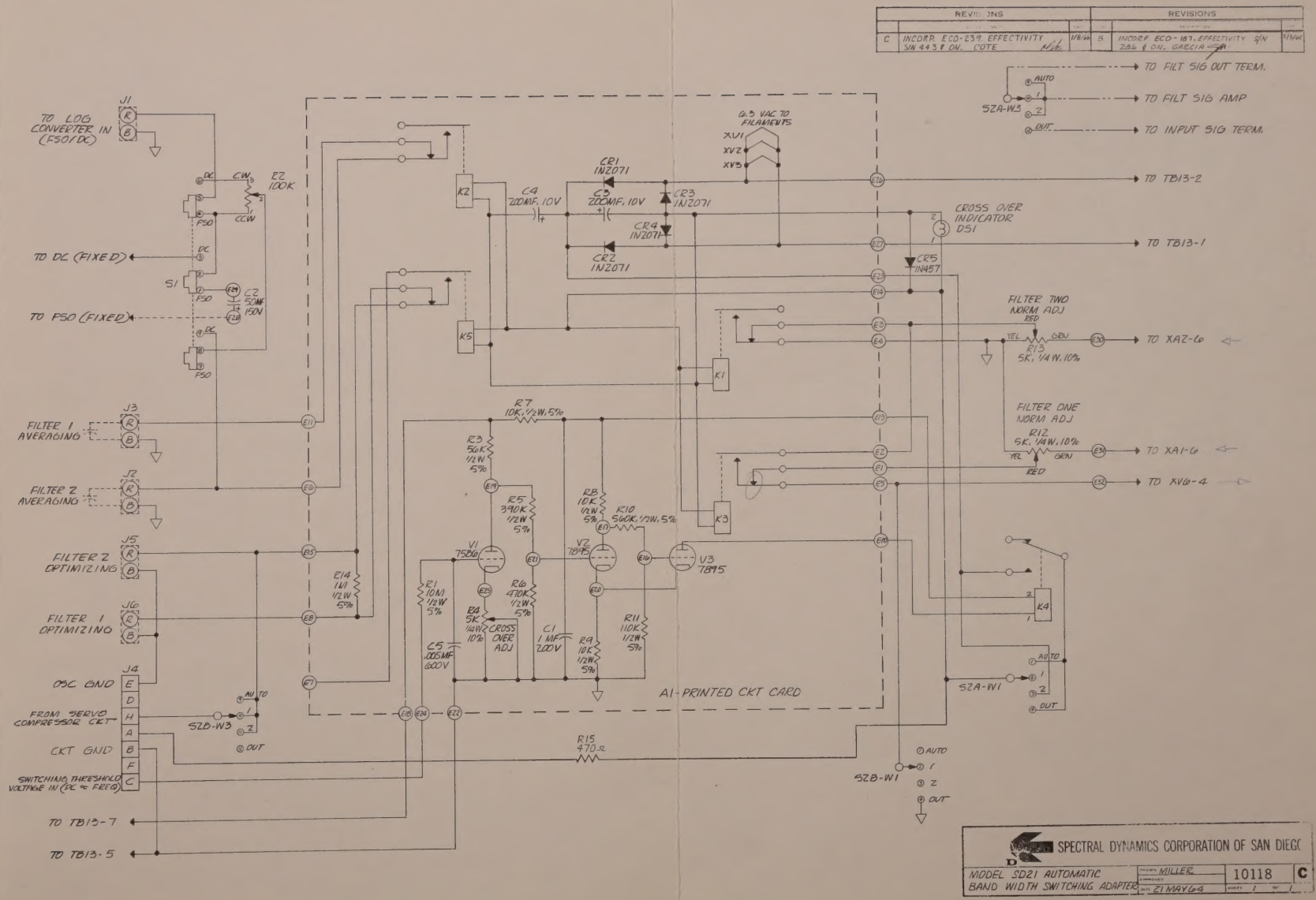
$$\text{Sweep Rate Setting (DEG/MIN)} = \frac{50 \text{ DEG}}{5.3 \text{ MIN}} = 7.4 \text{ DEG/MIN}$$

(b) Frequency Range = 100 - 3,000 CPS for 20-CPS filter which is 107 degrees on the B & K dial.

$$\text{Sweep Rate Setting (DEG/MIN)} = \frac{107 \text{ DEG}}{12 \text{ MIN}} = 8.9 \text{ DEG/MIN}$$

G. Calibrate the Analyzer to the Plotter.

Follow the procedure outlined in paragraph 3-7, Setup #1.



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MODEL SD21 AUTOMATIC BAND WIDTH SWITCHING ADAPTER

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